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Wastewater Treatment Facilities

training manual

Environmental Protection Agency

JULY 1971

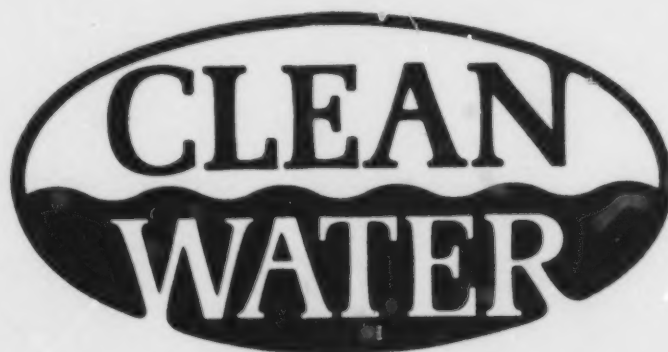
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PB 214 516

**PLANNING, DEVELOPMENT & MANAGEMENT
OF WASTEWATER TREATMENT FACILITIES**



TRAINING MANUAL

**ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PROGRAMS**

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268

PLANNING, DEVELOPMENT & MANAGEMENT OF WASTEWATER TREATMENT FACILITIES

This course is intended for planning and management personnel from public and private agencies planning to install new wastewater treatment facilities or to undertake major construction to improve existing facilities.

**ENVIRONMENTAL PROTECTION AGENCY
Office of Water Programs
TRAINING PROGRAM**

I

July 1971

FOREWORD

These manuals are prepared for reference use of students enrolled in scheduled training courses of the Water Quality Office, Environmental Protection Agency.

Due to the limited availability of the manuals, it is not appropriate to cite them as technical references in bibliographies or other forms of publication.

References to products and manufacturers are for illustration only; such references do not imply product endorsement by the Water Quality Office, Environmental Protection Agency.

The reference outlines in this manual have been selected and developed with a goal of providing the student with a fund of the best available current information pertinent to the subject matter of the course. Individual instructors may provide additional material to cover special aspects of their own presentations.

This manual will be useful to anyone who has need for information on the subjects covered. However, it should be understood that the manual will have its greatest value as an adjunct to classroom presentations. The inherent advantages of classroom presentation is in the give-and-take discussions and exchange of information between and among students and the instructional staff.

Constructive suggestions for improvement in the coverage, content, and format of the manual are solicited and will be given full consideration.

H.M. Freeman

H.M. Freeman
Chief, Direct Training Branch
Division of Manpower and Training
Water Quality Office
Environmental Protection Agency

TRAINING PROGRAM

Through the Water Quality Office, Environmental Protection Agency conducts programs of research, technical assistance, enforcement, and technical training for water pollution control.

Training is available at five installations of the Agency. These are: the National Training Center located at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio; the Robert S. Kerr Water Research Center, Ada, Oklahoma; the Southeast Water Laboratory, Athens, Georgia; the Pacific Northwest Water Laboratory, Corvallis, Oregon; and the Hudson-Delaware Basins Office, Edison, New Jersey.

The objectives of the Training Program are to provide specialized training in the field of water pollution control which will lead to rapid application of new research findings through updating of skills of technical and professional personnel, and to train new employees recruited from other professional or technical areas in the special skills required. Increasing attention is being given to development of special courses providing an overview of the nature, causes, prevention, and control of water pollution.

Scientists, engineers, and recognized authorities from other Agency programs, from other government agencies, universities, and industry supplement the training staff by serving as guest lecturers. Most training is conducted in the form of short-term courses of one or two weeks' duration. Subject matter includes selected practical features of plant operation and design, and water quality evaluation in field and laboratory. Specialized aspects and recent developments of sanitary engineering, chemistry, aquatic biology, microbiology, and field and laboratory techniques not generally available elsewhere, are included.

The primary role and responsibility of the States in the training of wastewater treatment plant operators are recognized. Technical support of operator-training programs of the States is available through technical consultations in the planning and development of operator-training courses. Guest appearances of instructors from the Environmental Protection Agency, and the loan of instructional materials such as lesson plans and visual training aids, may be obtained through special arrangement. These training aids, including reference training manuals, may be reproduced freely by the states for their own training programs. Special categories of training for personnel engaged in treatment plant operations may be developed and made available to the States for their own further production and presentation.

An annual Bulletin of Courses is prepared and distributed by the Water Quality Office. The Bulletin includes descriptions of courses, schedules, application blanks, and other appropriate information. Organizations and interested individuals not on the mailing list should request a copy from one of the training centers mentioned above.

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SECTION I

This section stresses responsibilities and working relationships among agencies concerned with water renovation in environmental rehabilitation. Current interagency developments are stressed.

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STATE RESPONSIBILITIES AND FUNCTIONS

I INTRODUCTION

A Individual states have the primary responsibility to provide for planning, development, management and enforcement of the various aspects of water pollution control within the state.

B This outline considers certain legal, administrative and regulating aspects of water pollution control in the State of Ohio.

II HISTORICAL DEVELOPMENT, REVISED CODE OF OHIO (1)

A Approval of plans for public water supply and sewerage improvements first was made the subject of legislative enactment in 1893. Authority of the Ohio Department of Health was extended and amplified by legislative enactments in 1925 and 1939.

B The original statutory authority relative to pollution of streams and public water supplies was enacted in 1908 with amplification and extension by the legislature in 1919, 1921, 1935, and 1945.

C The Ohio Water Pollution Control Act of 1951 as amended in 1967 (2) provides the basis for the present organization and structure.

III THE 1951 ACT (2) AMENDED IN 1967 ESTABLISHED WITHIN THE OHIO DEPARTMENT OF HEALTH A WATER POLLUTION CONTROL BOARD

A The Board consists of 6 members

- 1 The Director of Health (Chairman of the Board)
- 2 The Director of Natural Resources
- 3 The Director of Commerce

4 The Director of Agriculture

5 Two members appointed by the governor with the advice and consent of the senate, one of whom will be experienced in local government and one experienced in industrial activities.

B The Director of Health may exercise, in the name of the Board, all powers of the Board except the power to adopt and promulgate rules and regulations, revoke permits, issue or modify orders, and issue, deny, revoke or modify industrial water pollution control certificates.

C Powers of the Water Pollution Control Board

1 Develop programs for the prevention, control and abatement of water pollution.

2 Advise, consult and cooperate with other agencies of the state, the Federal government, other states, interstate agencies, and with affected groups.

3 Administer grants from the Federal government or other sources.

4 Administer state grants.

5 Encourage, participate in, or conduct studies, investigations, research, and demonstrations relating to water pollution.

6 Collect and disseminate information on water pollution prevention, control and abatement.

7 Adopt, modify, repeal and promulgate rules and regulations with respect to hearings, reports, water pollution certificates and procedures.

- 8 Issue, modify, or revoke orders subject to the Revised Code on sewage, industrial waste or other discharges to waters of the state, prohibiting or abating discharge, requiring treatment facilities, prohibiting additional connections to or extensions of sewers where such connections result in increased pollution.
- 9 Review plans, specifications, or other data relative to disposal systems in connection with issuance of orders, permits and certificates.
- 10 Issue, revoke, modify, or deny permits for the discharge of sewage, industrial waste, or other discharges, and for installation, modification or operation of disposal systems in line with technical feasibility and economic reasonableness in relation to public benefit. The Board shall specify rights of visitation by authorized representatives upon the premises of the permittee for compliance purposes.
- 11 Institute, or cause to be instituted, enforcement action proceedings in any court of competent jurisdiction.
- 12 Issue, deny, revoke, or modify industrial water pollution control certificates.
- 13 Certify to the government of the United States or any agency thereof, that an industrial water pollution facility is in conformance with state programs whenever such certification may be required under the Internal Revenue Code of the United States, as amended.
- 14 Exercise all incidental powers of the Revised Code of Ohio.

IV LEGAL REQUIREMENTS AND GUIDE FOR CLASSIFYING WATER SUPPLY AND WASTEWATER WORKS AND CERTIFYING OPERATING PERSONNEL(3)

- A The Ohio Department of Health is charged with responsibility for general supervision of operations of water and wastewater works.
- B The Public Health Council is empowered to make regulations applying to the State of Ohio as a whole. These regulations are known as the Ohio Sanitary Code. The Public Health Council shall:
 - 1 Make and amend sanitary regulations of general application.
 - 2 Take evidence in appeals relative to approval or disapproval of plans, locations, cost estimates, or other official actions.
 - 3 Conduct hearings.
 - 4 Prescribe by regulations the number and functions of divisions and bureaus, and the qualifications of chiefs thereof.
 - 5 Enact and amend bylaws.
 - 6 Consider any matter relating to preservation and improvement of public health.
 - 7 The council shall neither have nor exercise executive or administrative duties.

V REGULATIONS

- A Each person, firm, corporation, association, political subdivision, public institution, or place operating a water supply or wastewater works serving a

population, or population equivalent of over 250, shall place the works under responsible charge of a certified operator of a class at least equal to that required for the works classification.

B Wastewater works are classified to expedite administration of the supervisory program and to establish qualifications for operating personnel.

- 1 A system of rating (3) assigns rating values according to the number of unit operations, the complexity of the plant, the receiving waters, population equivalent and certain other items.
- 2 A Class I certification includes 1-29 rating points; Class II, 30-49; III, 50-64; and Class IV, 65 and over.
- 3 An appropriate certificate shall be issued to operators qualified to operate plants of a given plant classification. A certified operator is considered qualified for responsible charge of a class of plant equal to or lower than that of the grade of certification earned.
- 4 The Director of the Department of Health shall provide for the examination of persons desiring certification based upon satisfactory health, character, and morals, a high school or equivalent education, and at least one year of experience in a wastewater works for Class I, three years for Class II and five years for Class III. Education or experience may be partially substituted according to the judgment of the Board of Examiners acting for the Director.

VI PROCEDURES FOR OPERATOR CERTIFICATION (4)

The Division of Engineering with the assistance of the Advisory Board of Examiners on behalf of the Director of Health, carries out a program of training and certification as a first step to enhance continuing competent operation of public facilities for water and wastewater. More

and better facilities will be required in the future. Continuing training is a base from which high caliber, dedicated operators are developed for the communities of Ohio.

A Applicants for certification by the Ohio Department of Health should be high school graduates or equivalent. The Department encourages non-graduates to take a General Education Development Test; passing the test is considered equivalent to a high school diploma.

B Technical Education:

Applicants who do not have a college level degree in engineering or in the basic sciences are urged to take advantage of a series of courses given at various locations in the State of Ohio. These courses are designed to provide a basic understanding of chemistry, physics, microbiology, sanitary science, and works operation necessary for competent supervision, operation, maintenance, and reports to competent authority required of such operation.

- 1 Course I is designed for partial preparation of applicants for Class I examination for certification. It is commonly given at local high schools one evening per week for fifteen or more weeks. Professional teachers provide instruction in mathematics and sciences. Certified operators provide instruction in works operation.
- 2 Course II is designed for partial preparation of applicants for Class II certification. It is held at five locations in the state in the form of one-day meetings one month apart for five or more sessions. Certified operators and Division of Engineering personnel provide instruction.
- 3 Course III is designed for partial preparation for Class III certification. It takes the form of a workshop session at a central location, usually a three-day meeting, for presentation and discussion of major problems by works operators, state personnel and visiting participants.

State Responsibilities and Functions

- 4 Sectional meetings of the Ohio Water Pollution Control conference, the State Convention, and other technical meetings, are used for personnel development for continuing education.
- C The Ohio Operator Training Committee is charged with arrangements for collecting, management, and disbursement of funds, arrangements for instructors, meeting sites, instructional materials, work sheets and backup materials.
- 2 Ohio Water Pollution Control Act, 1967. Water Pollution Control Board, Ohio Department of Health, 450 East Town Street, Columbus, Ohio 43216.
- 3 Legal Requirements and Guide for Classifying Water Supply and Wastewater Works and Certifying Operating Personnel. Division of Engineering, Ohio Department of Health, Columbus, Ohio. 1964.
- 4 Policies and Procedures, Advisory Board of Examiners and the Division of Engineering for Certification of Operators of Water and Wastewater Works. Division of Engineering, Ohio State Board of Health. 1965.

ACKNOWLEDGMENT:

This outline was prepared from materials and information provided by J. E. Richards, Chief, and T. W. Hagerty, Division of Engineering, Ohio State Board of Health.

REFERENCES

- 1 Statutory Authority of the Department of Health, State of Ohio, in Matters Pertaining to Water Supply, Sewerage, Sewage, and Industrial Waste Disposal and Water Pollution Control. Division of Sanitary Engineering, Ohio Department of Health. August 1958.

This outline was prepared by F. J. Ludzack, Chemist, National Training Center, OWP, EPA, Cincinnati OH 45226.

LOCAL RESPONSIBILITIES AND FUNCTIONS

I INTRODUCTION - A BRIEF HISTORY

Over a period of some thirty years, beginning in the 1920's, Hamilton County established fifteen sewer districts, covering parts of the County's unincorporated areas, all of some of the existing municipalities, and parts of some of the municipalities.

As a result of annexations, changing corporate limits, records which were not kept updated, and for many other reasons it has been virtually impossible to trace the specific history of the County's system.

In 1955 the fifteen districts were consolidated into one by Resolution of the County Commissioners.

In 1963 the district was expanded to include the balance of the unincorporated area.

In that year the County's proposed \$60 million dollar sewer bond issue was badly defeated by the electorate.

The County was in desperate need of money for sewer construction; the State was threatening to curtail further construction in the County.

The City of Cincinnati too was going to be faced with financial difficulties. The sewerage service charge rates of the City's system were going to have to be raised to provide funds for required secondary treatment. Also the City needed money for much needed sewer work with little likelihood of receiving a favorable vote for the issuance of multimillion dollar sewer bonds.

Obviously, something had to be done.

II FORMATION OF METROPOLITAN SEWER DISTRICT OF GREATER CINCINNATI

In late 1967, discussions began between the County and Cincinnati on the possibility of a merger.

Under the Ohio Revised Code Chapter 6117, the County Commissioners may establish sewer districts, rates, etc.

Further, under Section 307.15 ORC the County may contract for the operation of governmental functions.

Had it not been for this latter Section, The Metropolitan Sewer District might not have gotten off the ground.

At any rate, within a few months, the various items were ironed out. The City of Cincinnati would join the County Sewer District and at the same time enter into an agreement whereby the City would manage the District.

Under the agreement, the City was to set up a separate department which would manage the district.

To develop the managing department, the City took all of the personnel from its Division of Water Pollution Control (176), the Sewer Design Section of the City's Engineering Division (26), the Sewer Maintenance Section of the Highway Maintenance Division (77), together with the personnel of the County Sanitary Engineer's Office (101).

In our particular situation, the agreement whereby the City would manage the District was the best approach since the City's functional departments would be immediately available to the new department for such services as:

- A Personnel
- B Civil Service
- C Purchasing
- D Solicitor
- E Real Estate
- F Highway Maintenance
- G Public Works (Engineering, heavy construction inspection)

Additionally, while the County Sanitary Engineer's Office had been in existence only a relatively few years, all of the City's groups had been in existence a long time with a national reputation.

III DEPARTMENTAL ORGANIZATION (See attached organizational charts)

- A Division of Administration
- B Division of Operations
- C Division of Technical Services
- D Division of Sewer Maintenance

IV DIVISIONAL FUNCTIONS

A Division of Administration

- 1 Establish and enforce rules and regulations for the design, construction, maintenance, operation and use of all public sanitary and combined sewers
- 2 Review and approve plans for all privately constructed sewerage facilities connected to the District's facilities, or to be turned over to the District for operation upon completion
- 3 Establish rates for use of sewerage facilities
- 4 Prepare and implement a continuing Capital Improvement Program
- 5 Prepare and keep current an overall sewer plan, both short and long range
- 6 Maintain all personnel records
- 7 Maintain all financial and cost records
- 8 Maintain a safety program

B Division of Operations

- 1 Operate and maintain all treatment facilities
- 2 Operate and maintain all pumping stations
- 3 Industrial waste and plant laboratories together with stream quality survey program

C Division of Technical Services

- 1 Prepare plans and specifications for sewers and package pump stations
- 2 Issue tap permits, licenses and maintain related records
- 3 Inspect the construction of sewers and sewer connections
- 4 Carry out sewer gauging and sampling

D Division of Sewer Maintenance

- 1 Maintain all public sewers and appurtenances
- 2 Maintain house laterals from public sewer to property lines
- 3 Carry out a continuing sewer inspection program

This outline was prepared by C. M. Vollmer, P.E., Principal Engineer, Department of Sewers, Metropolitan Sewer District of Greater Cincinnati, Cincinnati, Ohio 45204.

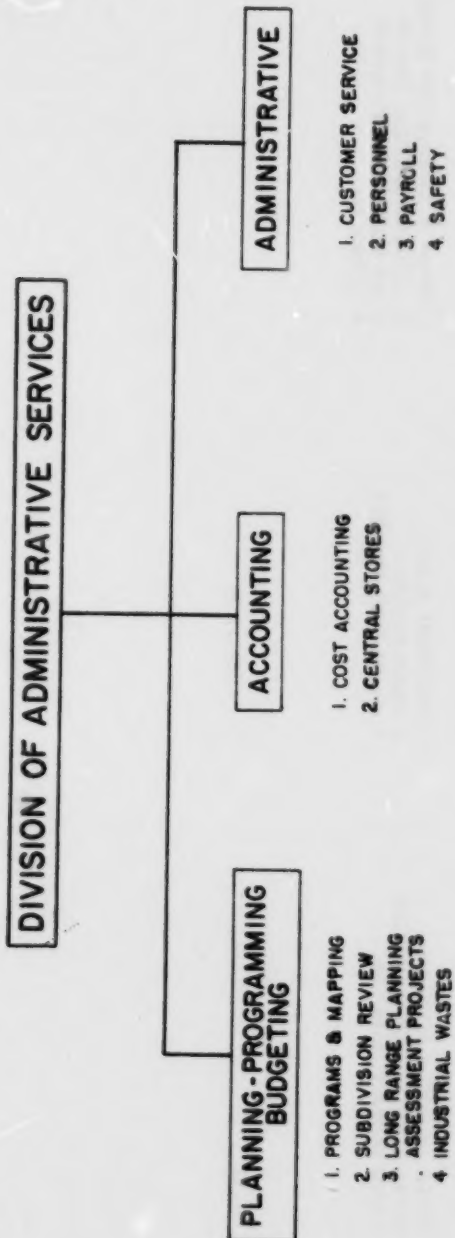


CHART I

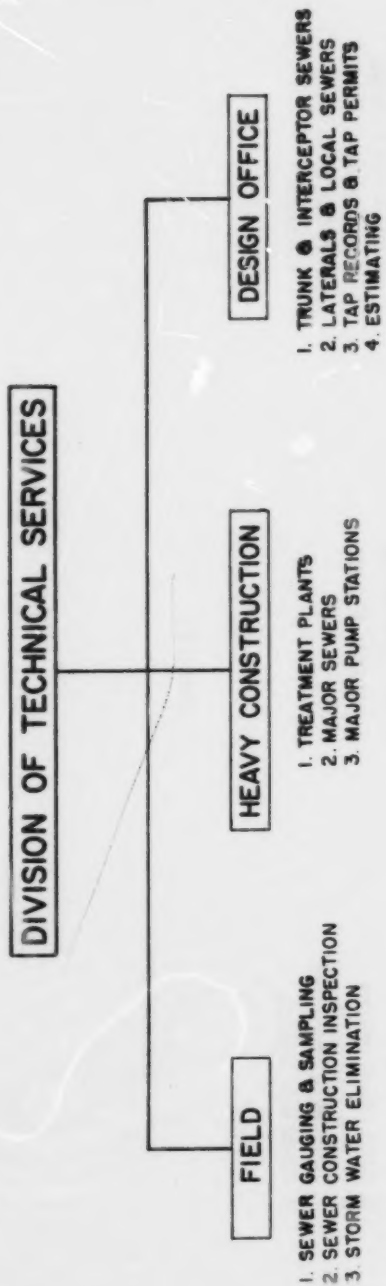


CHART II

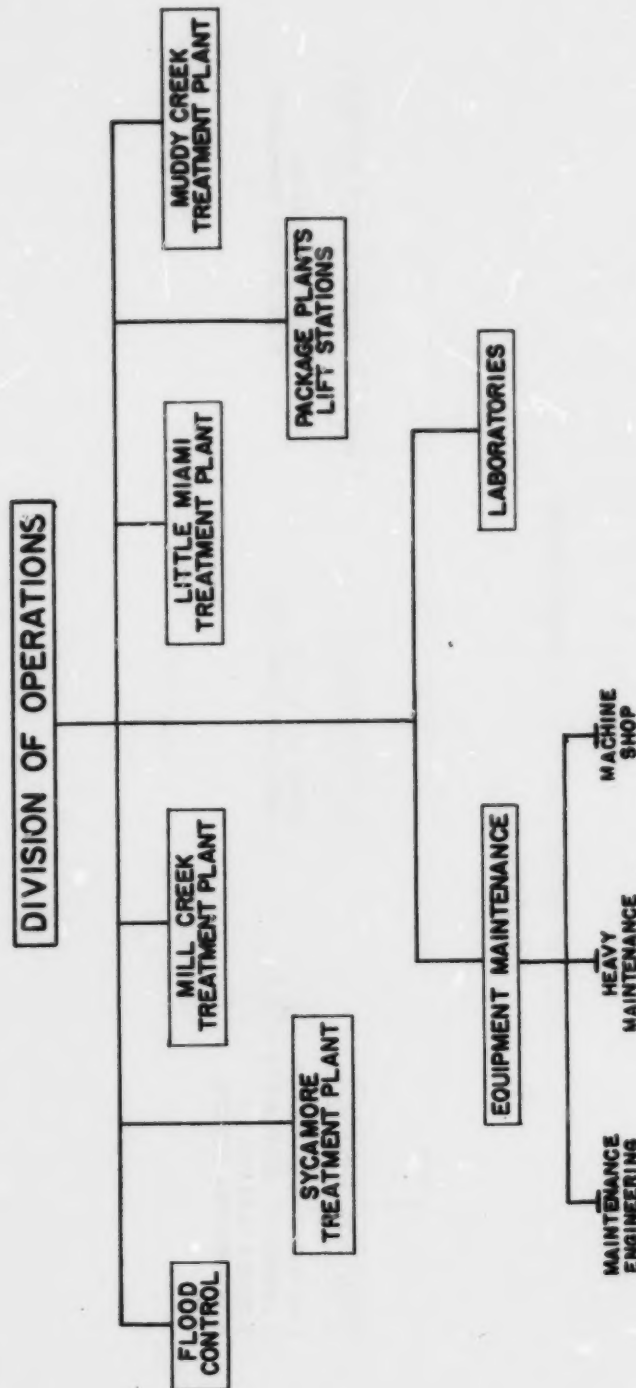


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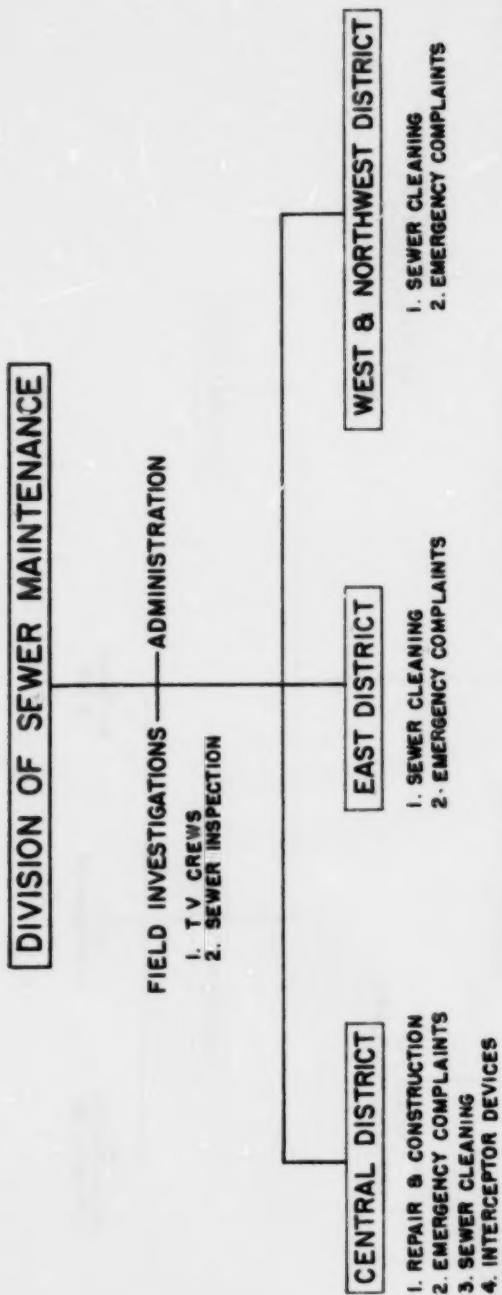


CHART IV

THE CONSULTING ENGINEER'S FUNCTIONS

I INTRODUCTION

The consulting engineer participates in many phases of a pollution control project, from preliminary broad-scale planning through design, construction and operation. His general function is to supply the integrated technical staff experienced in the many elements of pollution control engineering including sanitary engineers, chemists, biologists, architects, construction engineers, rate experts and planners.

His specific function is to translate the general pollution control objectives into a concrete plan and then into a working treatment or collection facility.

This discussion considers the consulting engineer's functions in each phase as the project progresses from initial planning to operation.

II PRELIMINARY PLANNING

The preliminary planning phase of a pollution control project involves the definition of general objectives, the determination of the geographical area to be included and the integration of water quality standards or criteria to be met. This phase is carried out by various Federal, State and local agencies, but may include services of a consulting engineer in providing some of the technical functions.

A Acquisition of Basic Data for Planning

- 1 Areawide water quality surveys to determine chemical and biological condition of streams
- 2 Geographic, demographic and socio-economic data

B Optimization of Units and Subdivisions for Planning Purposes

C Projection of Future Water Management Needs

D Assistance in Establishing Goals and Objectives

III PROJECT STUDY AND REPORT

After the establishment of general objectives and definition of the project service area, the consulting engineer prepares a detailed study and report which defines the specific problem and presents a detailed project plan for meeting the established goals. This includes:

A Study of existing facilities to determine shortcomings and needs for improvement

- 1 Review past operating data and experience
- 2 Determine sources of polluting discharges
- 3 Effectiveness of existing processes to handle wastes

B Prepare projections of future needs for design purposes

- 1 Projected population and wastewater flows from area to be served
- 2 Expected wastewater characteristics
- 3 Industrial waste and storm water contribution
- 4 Changes in degree of treatment expected during life of project
- 5 Site requirements

C Determine degree of treatment required and treatment process to be employed with consideration of flexibility to meet future changes.

- 1 Laboratory or pilot plant work if required to determine treatability of wastes by processes under consideration.
- 2 Consider alternate treatment processes available, and prepare preliminary designs for each.
- 3 Consider operating staff available, and demands of each process considered on personnel, equipment, chemicals, and plant site.
- 4 Select optimum treatment process for given situation on basis of:
 - a Ability to provide required degree of treatment
 - b Versatility to meet future demands
 - c Flexibility of process operation to accommodate variations in wastewater
 - d Operating and maintenance skills required
 - e Total annual costs for both capital and operation and maintenance

D Develop Project Plan and Cost Estimates

- 1 Preliminary design of the selected process to determine structure and equipment sizes
- 2 Optimum layout of structures on plant site
- 3 Preliminary estimates of costs for budget purposes
- 4 Study of financing plans available
- 5 Provide written report for review and approvals

IV DETAILED DESIGN, PLANS AND SPECIFICATIONS

In the detailed design phase, the project plan is designed in detail, and plans and specifications are prepared for use in construction. Based on the final design, detailed cost estimates are prepared, and the project is readied for construction.

A Preparation of Detailed Engineering Designs

- 1 Field surveys at site
- 2 Sanitary, structural, mechanical, electrical, architectural and hydraulic design computations
- 3 Select hardware and process equipment for integrated process

B Prepare construction plans and specifications, with contract and proposal documents for bidding purposes.

C Detailed Estimates of Cost and Qualities of Work

V CONSTRUCTION PHASE

During the construction of the project, the consulting engineer may provide all or part of the supervisory functions, depending on the client's staff capabilities.

A Assist in receiving and evaluating bids, and awarding construction contracts

B Assist in preparing applications for grant assistance

C Supervision of construction to assure compliance with plans and specifications

- 1 Review of shop drawings and equipment submissions

- 2 Resident engineer and inspection at site of work
- 3 Progress estimates for periodic payments to contractor
- 4 Inspect and certify completion and acceptance of project

VI OPERATION OF FACILITIES

The consulting engineer often assists in the operation of treatment plants, both in start-up and in continuing operation.

- A Furnish written basis of design describing the facilities and their function in detail.
- B Prepare an operating manual for guidance of the plant operators.
 - 1 Routine operation procedures, and expected performance of each process
 - 2 Modifications to process to meet unusual conditions
 - 3 Emergency procedures for power failure, equipment breakdown, etc.
- C Provide on-site operating engineer to assist in start-up and for consultation during initial operating period.
- D Periodic review of operation and advice on modifications and improvements in plant operation or maintenance
 - 1 Process operation and equipment
 - 2 Personnel requirements and training
 - 3 Budget requirements

VII MISCELLANEOUS CONSULTING SERVICES

In addition to the functions outlined above, the consulting engineer can provide expert service in several miscellaneous categories which may or may not be required in each case.

A Engineering Services of Various Types

- 1 Industrial waste surveys and control ordinances
- 2 Laboratory testing services
- 3 Research and development, and pilot plant studies
- 4 Feasibility studies of new processes or equipment
- 5 Planning and consultation

B Fiscal and Administrative Matters

- 1 Sewerage service charge rate studies
- 2 *Valuations and appraisals
- 3 Coordination in multi-agency projects
- 4 Expert witness services in cases of litigation.

This outline was prepared by George D. Simpson, Member and Project Manager, Havens and Emerson, Ltd., Consulting Engineers, Cleveland, New York, E. Paterson, NJ.

SECTION II

An overview of treatment options includes conventional, advanced, biological, physical-chemical and small waste treatment systems. Characteristics advantages and limitations are considered.

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CONVENTIONAL TREATMENT OVERVIEW

I Wastewater treatment means many things, depending upon who is considering it and whether they are paying for it, live downstream from it, or discharging to it. Prior training, experience, contacts, interest and personal involvement also affect viewpoints. This outline is intended to clarify certain aspects of treatment.

II Certain realities are inescapable in relation to treatment that affects every aspect of it.

A There are no holidays or time off in treatment operations.

- 1 Wastewater continues to flow 24 hours per day, 365 days per year.
- 2 Continuous treatment is essential to protect downstream resources.

B Many existing facilities require major upgrading in treatment performance.

- 1 Design, capacity, obsolescence, motivation, insufficient personnel of the required competence level, population and industrial growth, all contribute to less than desired effectiveness.
- 2 Facilities designed for domestic wastewaters are expected to treat garbage, industrial organics, pharmaceuticals, plastics, etc.
- 3 Production favors larger and larger central facilities for every activity. This alters concentration, hydraulics, and changeability for the treatment operations.

C Economics control both support of and limitation in treatment.

- 1 We pay for that which we find most attractive regardless of real benefit to us.

2 We are not inclined to pay for unseen items directly benefiting others.

3 Fixed bonded debts carry penalties for default. Penalties are less obvious for operation and maintenance.

III Various elements of treatment are considered in detail in other course presentations. This outline attempts to clarify interrelationships of one to another. It must be recognized that treatment facilities should reflect a particular situation and its needs or objectives. That required at one installation may not be necessary at another. Treatment facilities may achieve objectives by alternate routes, depending upon nature of the load, land availability, amount of hydraulic or organic loading, available water and reuse requirements. Custom is a potent factor.

Facilities tend to be repeated for a given size, region, or use, but all have individual characteristics depending upon the local situation.

A Collection of Wastewater

- 1 Used water cannot be treated if it isn't conveyed to the treatment plant.
- 2 Long lines, mixed sanitary industrial and storm water affect treatability.
- 3 The collection system cost usually is much greater than the cost of treatment facilities. Its effectiveness limits what can be done in treatment and to a high degree what must be done.

B Pretreatment commonly is used to prepare the flow for subsequent operations such as:

- 1 Coarse screening generally of one to five inch opening in the form of bars spaced to remove rocks, roots, and rags.

- 2 Grit removal commonly an enlargement in the channel to permit deposition of sand and gravel.
- 3 Comminution - a grinding operation to reduce the size of the larger masses of material.
- 4 Odor control may include addition of chlorine or pre-aeration to freshen the wastewater, oxidize or promote later separations or conversions.

C Primary treatment commonly involves detention in a natural or engineered basin for one to four hours to permit separation of floatable or settleable material from the used water.

D Secondary treatment is directed toward the conversion of colloidal and dissolved materials into a form in which they may be separated from the water. This commonly includes biodegradation with partial oxidation in process. Various modifications or facilities may be used depending upon requirements and space availability such as:

- 1 Activated sludge
- 2 Trickling filtration
- 3 Ponds or lagoons

E Advanced Waste Treatment

This topic is considered in other presentations but the objectives are to improve quality of the discharged effluent for reuse requirements by removal of items incompletely removed by other processes or to remove certain components normally passing through other processes. Physical, chemical, or biological methods may be applied before, during, or after treatment, as indicated for the particular situation.

F Solids Disposal

Each of the treatment stages previously enumerated results in some form of solid concentrate or sludge for disposal in a nonpollutional manner.

The principal problem of water pollution control lies in the disposal of these solids among air, water, and land.

- 1 Returning that which was removed from water to the water again defeats the purpose of the takeout operation.
- 2 Land application by burial, cultivation, or spreading is feasible if an isolated site is available.
- 3 Incineration is effective providing the various unstable materials are completely burned so that volatile oxides instead of partially burned carbon, dust, and fumes are discharged.
- 4 Water is an active reaction media. Oxides in the air and oxides in the soil will eventually recycle in nature but the process is slower when the gas and solids are physically separated than when they are intimately mixed in the water phase.

This outline was prepared by F. J. Ludzack, Chemist, National Training Center, Water Quality Office, EPA, Cincinnati, OH 45226.

WASTEWATER TREATMENT: SCHEMATICS, FUNCTIONS, AND OPTIONS

I INTRODUCTION

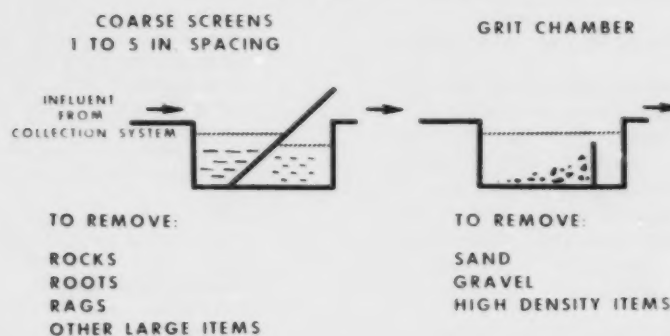
- A Wastewater treatment facilities are engineered to recondition used water for beneficial reuse. Traditionally these facilities are designed to achieve in a shorter time and smaller space a similar degree of self purification that may occur naturally under low load conditions. Current thinking stresses removal of many items that are ineffectively removed by natural means.
- B Increasing populations and urban development has increased stress on water renovation for reuse. Effluent and stream criteria are being used by State, Regional, and Federal Authorities for standards and enforcement to upgrade water resources. These are dynamic standards expected to require more treatment for more items as the situation requires.
- C It is technically possible to recondition used water for any reuse purpose. Economics, public apathy, opinions, operational competence enthusiasm and enforcement commonly limit what will be done in a given situation.
- 1 Certain items are much more difficult to remove from used waters than others. Special procedures are required to supplement conventional treatment when the hard-to-remove items are present in significant amounts.
 - 2 Reuse water quality requires more consideration of effluent quality than of percentage removals. It is likely to cost more to upgrade treatment from 90 to 99% than to obtain the first 90%. Reuse after 90% treatment may be unattractive.
- D The following schematics present an overview of what may be found in a wastewater treatment plant and the functional purpose of various items. These are not intended to be complete or detailed. Other sources of information provide details.
- 1 It is not possible to generalize what shall be included in a given plant. The State agency or agencies designated for water quality responsibility have primary interest. Planning agencies, Construction Grants, Professional Associations and other groups have responsibility in the use of public funds to meet the needs of a given situation.
- 2 Plant design is the responsibility of a professional consultant who is designated to select the hardware and processes to meet the needs of the situation as defined by planning agencies. Information gathered from the record, current and projected activities of the contributing population, nature of the wastewater load, quality requirements of the receiving water, availability of water, site survey, treatment, experience or studies all contribute to design consideration.
 - 3 The designed plant does not become a functional reality until construction and operation has been financed with people competent to do the job. "Too little-too-late" is a common problem in treatment facilities because of losses in transit and/or the fact that needs grow faster than available facilities and manpower.
- E Options in treatment technology must be qualified. There are many alternate routes for achieving a given treatment objective. They are not equals with respect to cost, time, space, performance, operation, opinion, etc.
- 1 Local opinion often favors one treatment option over another that is considered better in terms of cost efficiency and dependability by another area and another group.
 - 2 Relative cost for land, hardware, and operation are a large factor in process selection.
 - 3 Established practice, good or indifferent tends to perpetuate itself. It is much less effort to "sell" a well known process than to design one precisely fitted to the situation.

This outline was prepared by F. J. Ludzack, Chemist, National Training Center, OWP, EPA, Cincinnati, OH 45226.

The following schematics and options are for orientation purposes only. They are not intended to illustrate all possible treatment schemes or any one treatment plant. Implications of preference are not to be assumed by inclusion, omission or order of appearance.

19 illustrations to follow

WASTE WATER TREATMENT SCHEMATICS PRE-TREATMENT



TO PROTECT SUBSEQUENT PROCESS
EQUIPMENT AND OPERATIONS

WASTEWATER TREATMENT OPTIONS COARSE SCREENING

MANUALLY OR MECHANICALLY CLEANED FIXED OR
MOVING RAKES CLEANING

CYCLE ACTUATED BY : TIME
OPERATOR
PRESSURE OR LEVEL CONTROL

SCREENINGS DISPOSAL

BURIAL
DRYING & INCINERATION
GRINDING & RETURN TO PROCESS WATER

WASTEWATER TREATMENT OPTIONS GRIT REMOVAL

LOCATION

COLLECTION SYSTEM
PLANT HEADWORKS
IN PROCESS

TYPES OF EQUIPMENT

LONG NARROW CHANNELS (HORIZONTAL FLOW)
CIRCULAR FLOW BASINS (CYCLONES)
UPFLOW TYPE BASINS
CENTRIFUGE EQUIPMENT
MANUAL OR MECHANICAL GRIT REMOVAL (SOME TYPES)
HYDRAULIC GRIT WASHING

GRIT DISPOSAL

BURIAL
FILL (OF WASHED MATERIAL)

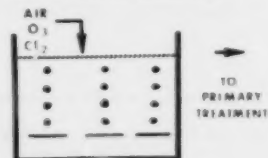
WASTE WATER TREATMENT SCHEMATICS PRE-TREATMENT

GRINDING (COMMINUTION)
AND/OR FINE SCREENS 0.04 TO 1 IN
SPACING



TO REDUCE SIZE OF MATERIAL
OR REMOVE
FIBER
STRINGS
CHUNKS
PLASTICS

PRE AERATION OR OZONATION
AND/OR PRE CHLORINATION



TO FRESHEN THE WASTE WATER
DISINFECTION
OXIDATION
REDUCE ODOR
IMPROVE LATER TREATMENT

TO PROTECT SUBSEQUENT PROCESS
EQUIPMENT AND OPERATIONS

WASTEWATER TREATMENT OPTIONS
SIZE REDUCTION AND/OR FINE SCREENS

COMMINUTION

HAMMER MILLS VARIABLE CLEARANCE
FIXED STATOR HIGH SPEED ROTOR SMALL CLEARANCE
HYDRAULIC SHEAR (CENTRIFUGAL PUMPS)
WITH OR WITHOUT OUTLET SCREENS
WITH OR WITHOUT TAKE OUT OF SELECTED MATERIALS

FINE SCREENS

VIBRATING
SUBMERGED DRUM
HYDROSIEVE
MOVING BELT MICROSCREENING

SCREENINGS DISPOSAL

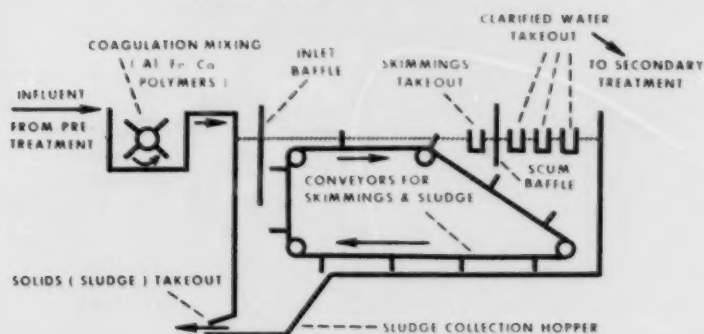
BURIAL
DRYING & INCINERATION
GRINDING & RETURN TO PROCESS

TAKE OUT OF FIBROUS MATERIAL FAVORS LATER PROCESSING

WASTEWATER TREATMENT OPTIONS
PRE-AERATION, PRE-CHLORINATION, OZONATION

TREATMENT	FUNCTION
1. Aeration (10 - 30 min.)	a. Satisfy immediate oxygen demand b. Decrease odor c. Improve later processing
2. Chlorination	Partial disinfection + group 1
3. Ozonation	Decrease odor primarily + group 1
4. Pressurized Aeration & Release	Floatation of grease, oil, solids May pressurize part or all of the flow
5. Additional Degritting during retention	

WASTEWATER TREATMENT SCHEMATICS PRIMARY SEDIMENTATION

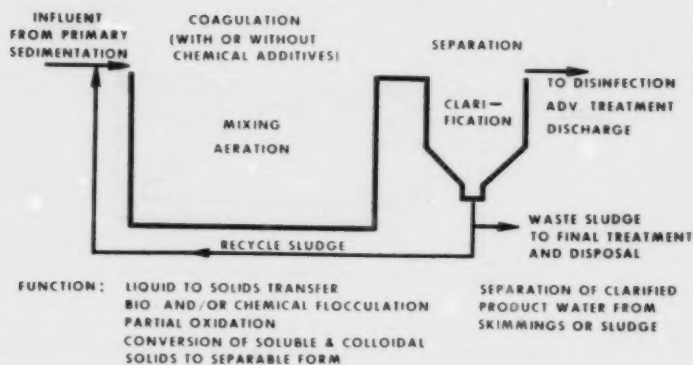


FUNCTION: TO SEPERATE FLOATABLE OR SETTLEABLE SOLIDS FROM THE CLARIFIED PRODUCT WATER

WASTEWATER TREATMENT OPTIONS PRIMARY SEDIMENTATION

1. MAY BE OMITTED BEFORE CERTAIN SECONDARY PROCESS
2. RECTANGULAR TANKS
SLUDGE TAKEOUT AT INLET OR OUTLET END
VARIOUS LENGTH/WIDTH/DEPTH CONFIGURATIONS
3. CIRCULAR TANKS
CENTER FEED OR PERIPHERAL FEED
VARIOUS WEIR ARRANGEMENTS
4. SLUDGE COLLECTION
DRAG OR FLIGHT BOARDS ON LINKED CHAIN
SUCTION MECHANISM - FIXED OR MOVING
ROTATING BRIDGE - SUCTION OR DRAG
5. TUBE TYPE - MOSTLY FOR SEC. CLARIFICATION
6. SLUDGE DRAW-OFF
PISTON PUMPS
CENTRIFUGAL PUMPS
AIR LIFT OR PNEUMATIC EJECTORS
SCREW TYPE PUMPS

WASTEWATER TREATMENT SCHEMATICS SECONDARY TREATMENT



WASTEWATER TREATMENT OPTIONS SECONDARY TREATMENT

1 ACTIVATED SLUDGE (FLUID SLIME SUSPENSION)

- a HIGH RATE > 1.0 lb. COD/ lb. MLVSS/DAY
- b CONVENTIONAL 0.4 - 1.0 lb. COD/MLVSS/DAY
- c EXTENDED AERATION < 0.4 lb. COD/lb. MLVSS/DAY
- d COMPLETE MIX OR PLUG FLOW
- e MECHANICAL, DIFFUSED AIR OR COMBINATION OXYGENATION
- f CONTACT, 2 STAGE, TAPERED AERATION, STEP FEED, KRAUSE PROCESS, CHEMICAL COAGULATION, N₂ OXID. RED

WASTEWATER TREATMENT OPTIONS

SECONDARY TREATMENT

TRICKLING FILTRATION (FIXED MEDIA SLIMES)

- a HIGH RATE 25 - 300 lbs. BOD₅ /1000cu. ft. OF MEDIA
- b LOW RATE 5 - 25 lbs. BOD₅ /1000 cu. ft. OF MEDIA
- c RECIRCULATING (OF CLARIFIED EFFLUENT, SLUDGE, OR MIXTURES)
- d SHALLOW OR DEEP BEDS
- e ROCK, SLAG, OR MANUFACTURED MEDIA
- f 2-STAGE, NATURAL OR FORCED DRAFT, COMBINED TRICKLING FILTRATION AND ACTIVATED SLUDGE

WASTEWATER TREATMENT OPTIONS

SECONDARY TREATMENT

OXIDATION PONDS

- A DEPTH : SHALLOW (1 - 5 FT) DEEP (5 - 25 FT)
- B TIME:
 - < 3 DAYS PRIMARILY SEDIMENTATION
 - 3 - 20 DAYS SUSPENDED SLIME GROWTH
 - > 20 DAYS GROWTH FLOCCULATION, DEPOSITION
- C SINGLE OR MULTIPLE PONDS
 - SERIES OR PARALLEL OPERATION
- D PRIMARILY AEROBIC, ANAEROBIC, FACULTATIVE
- E NATURAL OR FORCED AERATION & MIXING
- F RECIRCULATION (EFFLUENT, SOLIDS, OR MIXTURES)
- G LEVEL CONTROL : (OVERFLOW, PERCOLATION, EVAPORATION)
- H CLARIFICATION: INCIDENTAL OR SEPARATE
 - ENGINEERED OR NATURAL SOLIDS TAKEOUT

WASTEWATER TREATMENT OPTIONS

PHYSICAL - CHEMICAL TREATMENT

1. APPLICATIONS

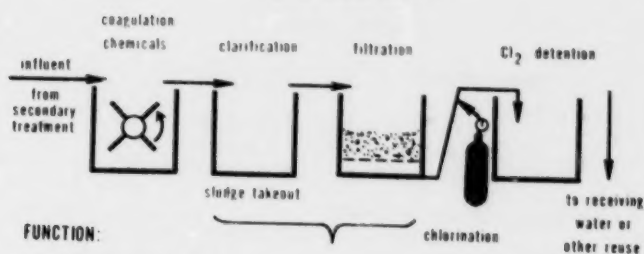
- A. RAW WASTEWATER
- B. IN PROCESS SUPPLEMENTATION TO BIOL. TREATMENT
- C. AFTER BIOLOGICAL TREATMENT

2 NATURE OF TREATMENT

- A. LIME COAGULATION
- B. ALUM OR IRON COAGULATION
- C. POLYMER COAGULATION
- D. AMMONIA STRIPPING
- E. CARBON ADSORPTION POWDER OR GRANULAR
- F. FILTRATION: (SAND, MIXED BED, SOIL MICROSTRAINING MOVING BED)
- G. ELECTROPHORESIS
- H. ION EXCHANGE
- I. DISTILLATION
- J. DISINFECTION
- K. CHEMICAL OXIDATION

WASTEWATER TREATMENT SCHEMATICS

TREATED LIQUID STREAM

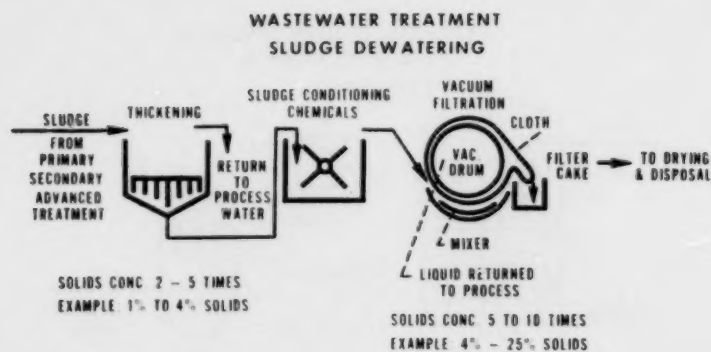


FUNCTION:

TO INCREASE POSSIBILITIES
FOR REMOVAL OF ITEMS
PASSING THROUGH
CONVENTIONAL
TREATMENT

TO PRODUCE A WATER
LOW IN DISSOLVED OR
SUSPENDED SOLIDS
(BIOLOGICAL OR OTHER)

TO DISINFECT
THE DISCHARGE



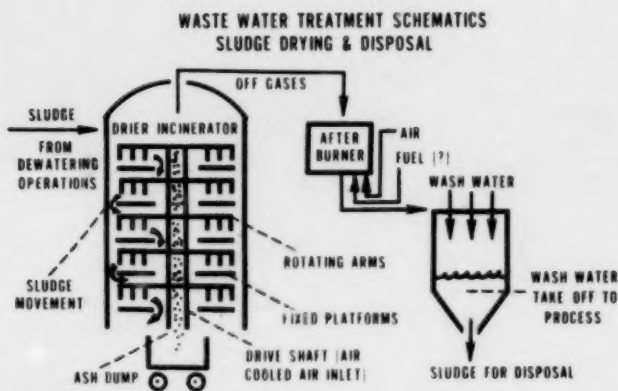
FUNCTION:

To reduce the water content of the sludge as much as possible by the most economical and feasible route for the situation.

To reduce the amount of water to be evaporated.

**WASTEWATER TREATMENT OPTIONS
SLUDGE DEWATERING**

- 1 LAND SPREADING (COVER CROP, TILLING, BURIAL)
- 2 SLUDGE DRYING BEDS
- 3 FILTRATION (VACUUM, VIBRATING SCREENS, SAND, ETC.)
- 4 INDUCED HEAT (SPRAY, ROTARY KILN, TRAY)
- 5 CENTRIFUGATION
- 6 FREEZING
- 7 CHEMICAL CONDITIONING
- 8 HIGH PRESSURE & TEMPERATURE DIGESTION
- 9 FLOTATION
- 10 SEDIMENTATION



FUNCTION:

To complete the drying operation and convert intermediate products to their highest oxidation state.

To stabilize off gases with respect to odor, oxidation state, and suspended solids.

**WASTEWATER TREATMENT OPTIONS
SOLIDS DISPOSAL METHODS**

- 1 LAND DISPOSAL: FOR REUSE, CROPPING, SOIL CONDITIONING, FOR ISOLATION, SANITARY FILL
- 2 INCINERATION: FOR CONVERSION TO INNOCUOUS GASES & ASH AT THEIR HIGHEST OXIDATION STATES
- 3 TRANSPORT TO REMOTE AREAS
- 4 SEA DISPOSAL: PREFERABLY DEEP WATERS
- 5 RECOVERY FOR REUSE
- 6 UNDERGROUND INJECTION

WASTEWATER TREATMENT OPTIONS
DISPOSAL ROUTES

1 RENOVATED WATER	RETURN FOR BENEFICIAL REUSE
2 GASES	
a. STABLE	RETURN TO THE ATMOSPHERE
b. UNSTABLE TOXIC ODOROUS	OXIDIZE, RECOVER, STABILIZE, CONVERT TO NON POLLUTIONAL FORM, BEFORE RETURN OF THE ACCEPTABLE FRACTION TO THE ATMOSPHERE
3 SOLIDS	
a. INSOLUBLE INORGANIC	RETURN TO THE LAND OR SEAS
b. SOLUBLE INORGANIC	RETURN TO SALINE WATERS, ISOLATED SALINE SUBSURFACE STRATA, RECOVER FOR REUSE
c. ORGANIC	STABILIZE, CONVERT TO GASES ACCEPTABLE FOR RETURN TO THE AIR AND SOLIDS ACCEPTABLE FOR RETURN TO THE LAND, ISOLATE SOLIDS WITH MINIMUM WATER CONTACT

FUNDAMENTALS OF ACTIVATED SLUDGE WASTE TREATMENT

I INTRODUCTION

The objective of biological or secondary waste treatment is the conversion of unsettled and dissolved organic matter that cannot be removed by primary treatment into cellular matter which can be removed by final settling. Microorganisms such as bacteria and protozoa use the organic matter as a source of food, oxidizing and converting the complex organics into simple organic and inorganic materials to obtain the energy necessary for their growth. Since successful waste treatment depends upon biological action, the waste treatment systems should be designed and operated to encourage the growth of the microorganisms involved. An understanding of the processes by which microorganisms bring about the conversions of organic materials and the factors which affect their growth will aid the engineer in designing biological processes capable of producing the degree of waste treatment desired.

II THEORY OF ACTIVATED SLUDGE WASTE TREATMENT

A Process Description (Figure 1)

Activated sludge waste treatment may be simply described as a continuous process in which flocculated biological growths are mixed with wastewater and aerated. The microorganisms utilize the organic waste matter as a food and energy source to sustain life. These biological growths and storage items are then separated from the treated waste by settling and are either wasted or recirculated for admixture with additional untreated waste.

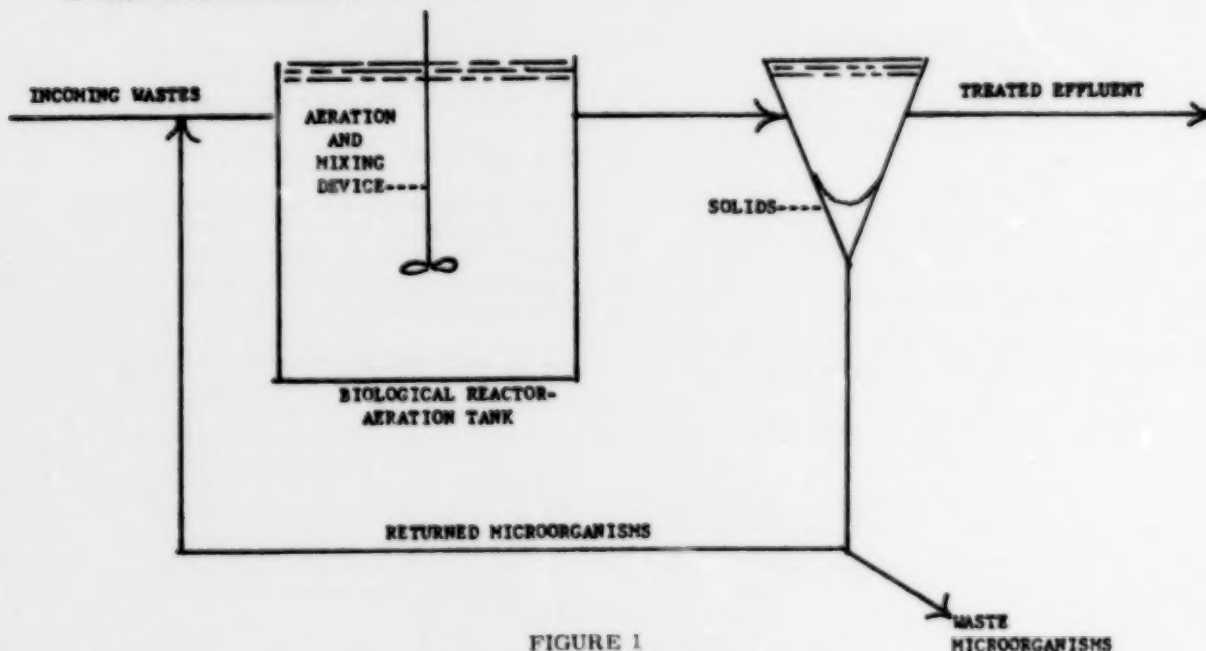


FIGURE 1
TYPICAL ACTIVATED SLUDGE UNIT PROCESS

There are three basic components in activated sludge waste treatment systems:

1 Aeration tank

- a Tank geometry must be considered.
- b Shape--can be rectangular or round.
- c Usually reinforced concrete construction.
- d Acts as reaction basin for activated sludge process.
- e Sizing and volume to provide necessary detention periods.

2 Aeration and mixing system

a Types of aeration devices

1) Mechanical surface aerators

- a) Bladed type, with or without draft tube -
Manufacturers: Mixco, Elmco, Infilco
- b) Pump type, submersible with draft tube -
Manufacturers: Wells, Chainbelt, Ashbrook
- c) Brush type -
Manufacturers: Kessner, Beloit-Passavant, Lakeside

2) Diffused air systems

- a) Low pressure air supplied by blowers or compressors.
- b) Air diffusers set near aeration tank bottom.
- c) Diffusers may be porous plates, porous tubes or air jets.
Manufacturers: Dorr-Oliver, Hinde

- b Purpose - to mix incoming waste with returned activated sludge containing seed microorganisms.

- c Activated sludge process utilizes aerobic or facultative microorganisms primarily bacteria with molds yeasts protozoa (slime organizing) - need continuous air supply to maintain aerobic conditions and mixing to maintain a fluid suspension and contact in the aerator.

3 Final settling tank

- a Integral and very important part of system.
- b Purpose - to separate activated sludge from liquid.
- c Activated sludge must be settled out and returned before it becomes anaerobic.
- d After settling the overflow liquid should be stabilized and clarified to meet discharge requirements. Scum control is advisable to upgrade effluent quality. Underflow activated sludge solids should be suitable for return to process for treatment of incoming wastewater.

B Biological Growth Characteristics

- 1 The growth of a mass of microorganisms, as a function of time after they have been mixed with an organic waste, passes through three major phases as shown in Figure 2.
 - a Logarithmic growth phase -- the first or log phase takes place when the organic waste concentration surrounding the microorganisms is high. Here, the rate of growth is limited only by the rate at which the microorganisms can consume the waste. Under these conditions the mass increases logarithmically, doubling after each equal interval

of time. Initially, there is a very rapid increase in the population of microorganisms along with a rapid decrease in the amount of food matter or waste remaining available. At the same time, there is a proportional increase in the rate of oxygen utilization, also a continual increase in the total amount of oxygen consumed.

This phase is characterized by high food-to-microorganism ratios with emphasis on synthesis or the production of cellular matter; oxygen requirements approximate about 40% of the ultimate oxygen demand to produce energy for growth. The log growth phase produces a sludge mass that will not readily separate to produce a clear effluent. During conventional operation, the log growth phase is a characteristic of some favored fraction of the total population generally near the inlet.

- b Declining growth phase -- at some point, the amount of food matter remaining begins to limit the rate of growth. A situation now exists where there are many microorganisms and not enough food matter left to sustain them.

This phase begins at the point of inflection on both the food and microorganism curves. The rate of growth and oxygen utilization rate begins to taper off. Cannibalism among the microorganisms increases. The animal forms and bacteria must work harder for their food; they require additional energy and more ultimate end products (CO_2 and H_2O) are produced. The amount of synthesis and the amount of complete oxidation becomes equal; overall oxygen requirements are greater. Cell mass tends to become flocculent and improves liquid-solids separation.

- c Endogenous respiration phase -- when most of the remaining food has been converted to organisms or

storage products on or within cells the endogenous growth phase begins. Growth and oxygen utilization continues but at the expense of preformed organisms. The total organism mass decreases with each regrowth cycle because energy for regrowth is derived from oxidation of part of the cell mass or storage material to form CO_2 + water. This will continue as long as oxidative energy release is sufficient to support a new generation of cells. This is a starvation mode where the less favored cells must die to provide food for the next round of growth. The "survival of the fittest" takes precedence. About 60% of the ultimate oxygen demand is exerted during this phase. A majority of organisms in conventional activated sludge are maintained in this phase during aeration at load ratios commonly encountered. Solids-liquid separation is feasible because flocculent growths are favored when there are enough organisms to limit the proportion in the log growth phase.

2 Ranges of activated sludge waste treatment

In order to have an activated sludge process at all, it is important to maintain a biological sludge of good physical quality; it must flocculate well and settle rapidly. The ability to control solids in the system is the key to successful activated sludge operation. The microorganisms will perform best when they are fed the right amount of food for the condition. Overfed organisms will produce rapidly growing non flocculent growths (so called bulking condition); underfed likewise form a dispersed system.

Organisms will function effectively in treatment only when conditions are favorable for growth. The best engineering approach is to design for favorable growth conditions. Over the years, experience through trial-and-error operation has shown that there

are four possible ranges wherein it is possible to operate the process continuously in a satisfactory manner. These are indicated on Figure 3.

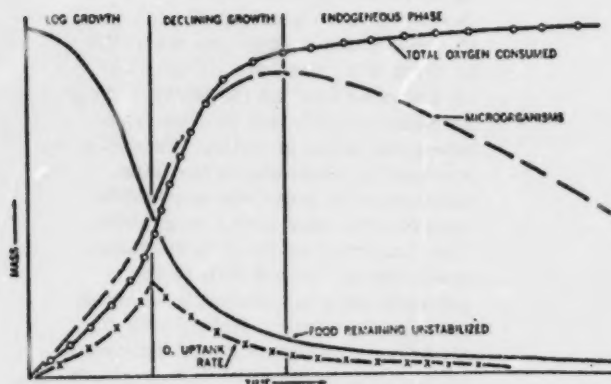


Figure 2—Ideal growth curve—batch operation.

Within each range there is optimum food-to-microorganism ratio which will produce the results characteristic for that system.

These ranges provide the four basic activated sludge processes which can be successfully used to treat organic wastes. These are:

- a Dispersed growth
- b High-rate
- c Conventional
- d Extended aeration

The differences between these operational ranges of activated sludge treatment mainly are the result of the ratio of food to microorganisms in process in descending order from a to d. This will be considered in another outline.

C Basic Biochemical Reactions

When organic matter is removed from solution by microorganisms, two basic phenomena occur; food is consumed by the organisms for energy production, and new cell matter is synthesized.

The rate at which these reaction occur, the amount of oxygen and nutrient required, and the quantity of excess biological sludge that is produced is of primary concern to the engineer responsible for the design and operation of activated sludge or biological treatment systems.

The basic biochemical reactions involved may be illustrated by the following equations:

- 1 Food + Microorganisms + $O_2 \rightarrow$
Cellular Matter + Energy + CO_2 +
 H_2O + NH_3
- 2 Organic Waste + Sludge + Air $\rightarrow$
Waste Sludge + Oxidation Products
- 3 Food/Microorganism Ratio + $O_2 \rightarrow$
Cells + Residues + Stabilized Water

└──────────┘
Sludge

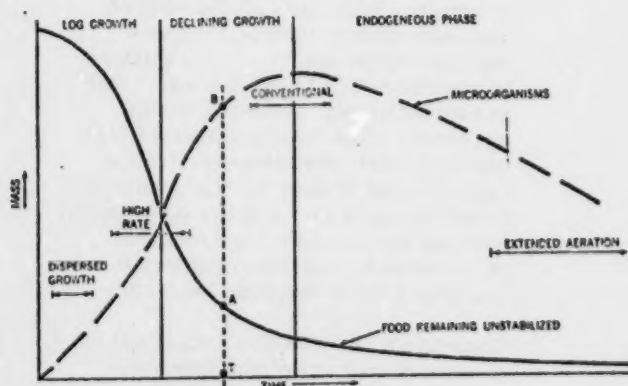


Figure 3—Ideal growth curve—continuous operation.

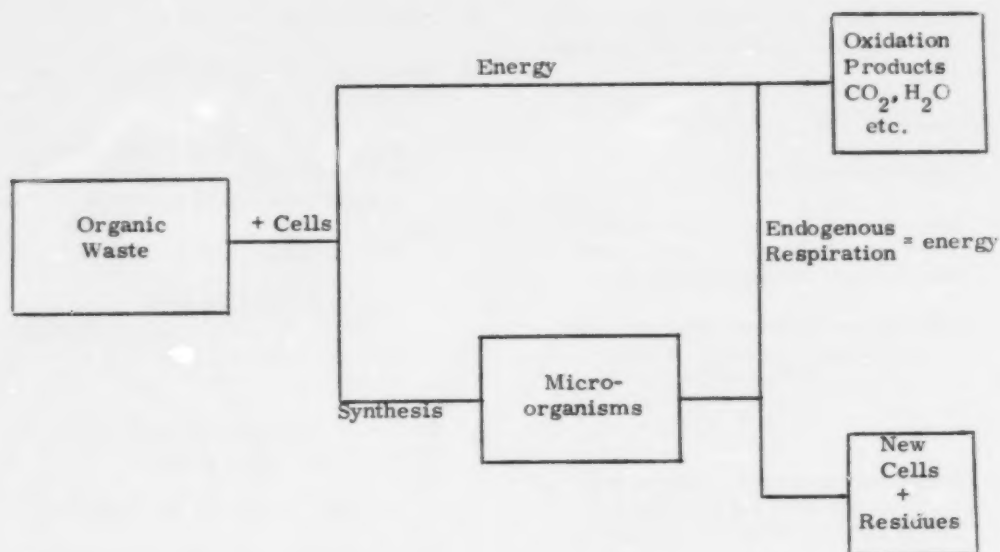


FIGURE 4. CONVERSION OF ORGANIC WASTES DURING BIOLOGICAL TREATMENT

D Environmental Factors

Assuming an adequate supply of nutrient material, the chief concern of the engineer is to bring together the right amounts of waste (food or BOD), biological culture (sludge or microorganisms), and air, for the correct period of time to achieve the desired end result while maintaining an easily handled physical system. After the selection of reaction conditions, it is essential that the plant design be tailored to satisfy the needs of the process. This means, first and foremost, creating an environment which will be optimum for the living organisms which form a part of the process. Environmental factors to be considered in activated sludge waste treatment include the following:

- 1 Food (nutrients)
- 2 Microorganisms
- 3 Mixing or contact
- 4 Detention time

5 Temperature

6 Air supply

7 Removal of waste products

8 Available growth factors and trace nutrients

9 pH

10 Freedom from toxic conditions

III OPERATIONAL CHARACTERISTICS

A Aeration Tank Mixed Liquor

- 1 Maintain dissolved oxygen greater than 2 mg/l -- range from 2 to 4 mg/l.
- 2 Suspended solids.
 - a Concentrations vary depending on process modification.
 - b Range from 1,000 to 4,000 mg/l.

- c Control by return sludge flow -- may vary from 25 to 100% of raw sewage flow.

3 Settleable solids

- a Very important quality.
- b Mixed liquor should settle readily in final settling tank to give a clear overflow and reuseable underflow.
- c Run test by allowing 1 liter sample of mixed liquor to settle in a liter graduated cylinder for 30 minutes and record volume of settled sludge in ml.
- d Sludge volume index -- the volume in ml occupied by 1 gm activated sludge after settling for 30 minutes.

$$S.V.I. = \frac{\text{ml settled sludge} \times 1,000}{\text{mg/l suspended solids}}$$

- e S.V.I.'s greater than 200 to 300 indicate trouble such as bulking sludge.
- f S.V.I.'s of 150 or less are usually desirable.
- g Advisable to check sludge compaction by test settling for 60 minutes.

B Final Settling Tank

- 1 Must remove settled activated sludge before it becomes anaerobic.
- 2 Provide scum control.
- 3 With proper solid-liquid separation, effluent is clear and sparkling.

IV OPERATIONAL PROBLEMS

The problems frequently encountered in the operation of activated sludge waste treatment plant, their possible causes, and suggested remedies are summarized in Table I which follows:

V CONCLUSION

A Advantages of Activated Sludge Waste Treatment

- 1 High degree of treatment provided with proper operation -- higher quality effluent than trickling filters.
- 2 Less land area required for installation.
- 3 Prefabricated treatment units are available in many sizes -- permits fast and relatively low cost field installation.
- 4 Lower total construction cost for larger sized plants.
- 5 Primary treatment not required.
- 6 Process is adaptable to a variety of topographic and climatic conditions.
- 7 Generally no odors, may be located near facility being served.
- 8 No dependence upon underground adsorption system for effluent disposal.
- 9 Small hydraulic head losses.
- 10 Most versatile of biological treatment processes -- good for treatment of most industrial wastes.

B Limitations of Activated Sludge Waste Treatment

- 1 Basic lack of understanding of basic process by both design engineers and plant operators.
- 2 Affected by shock loadings -- best applied to larger municipalities where variations in waste strength and flow tend to be equalized.
- 3 High power consumption and cost of operation.
- 4 Constant skilled and competent operation necessary.

TABLE I
SUGGESTED SOLUTIONS TO SOME OPERATIONAL PROBLEMS

Operational Problems	Possible Cause	Suggested Remedy
A Reduction in plant efficiency - high effluent BOD, COD	1 High organic and/or hydraulic loading	1 Reduce loading to capacity of system
	2 Toxic concentration of something	2 Analyze raw waste for heavy metals, potentially toxic organic compounds, etc. Locate the source of the offending discharge and prevent future excessive dumps. Return all of the sludge you can until the sludge adapts or regenerates
	3 Unfavorable carbon nitrogen phosphorus ratio	3 Add nitrogen and/or phosphorus in the ratio of at least (BOD/N/P) = 100/5/1
	4 Low MLSS concentration in aeration basin	4 Reduce sludge wastage, increase recycle rate
	5 Short-circuiting of wastewater through aeration basin	5 Increase power level to insure more complete mixing or provide for better physical distribution of the wastewater
	6 Unfavorable pH	6 Maintain pH within 6.5-9.0 range
	7 Insufficient dissolved oxygen in aeration basin	7 Increase oxygenation efficiency or capacity
B High suspended-solids conc. in effluent, poor plant efficiency, loss of sludge over final weirs	(Sludge Bulking)	
	1 Excessive organic loading	1 Reduce loading to system capacity or increase aerator solids concentration. Add coagulants
	2 Localized excessive organic loading because of plug flow	2 Increase mixing to approach a completely mixed condition by increasing power level providing baffling step feed or use coagulants to increase sludge concentration
	3 Overloaded final settling tank	3 Increase settling capacity

TABLE I (Continued)

C High suspended solids conc. in effluent, poor plant efficiency, loss of sludge over final weirs (continued)	4	Reduction of pH	4	Neutralize, add coagulants
	5	Predominance of filamentous microorganisms resulting from low N or P conc. in aeration basin	5	Add inorganic N or P to system
	6	Filamentous microorganisms persist in systems	6	Subject sludge to prolonged anaerobic holding time if possible, chlorinate, or purge system of sludge and reseed
	7	Gasified sludge caused by excessive anaerobic sludge holding time in clarifier	7	Increase sludge recycle rate and/or increase sludge wastage
	8	Excess sludge in clarifier caused by plugged sludge line	8	Reverse pump rotation, increase sludge recycle pumping rate as required to flush lines, or remove plug mechanically
	9	Excessive sludge in system	9	Expand sludge thickening and handling facilities; use primary clarifier for temporary sludge storage if feasible
	10	Floating solids	10	Provide scum control
	1	Oxygen deficit resulting from organic overloads	1	Increase blower capacity or add mechanical surface aerators to system
	2	Localized anaerobic "pockets" due to incomplete mixing	2	Increase aeration basin mixing power level, baffle system or step feed
	1	Decreased organic load	1	Adjust organic load, MLSS
D Excessive odors associated with designed aerobic systems (basin dissolved oxygen 0.5 mg/l)		insufficient MLSS conc., or excessive aeration		sludge waste rate, or surface aeration capacity as required
E Dissolved oxygen levels in aeration basin exceeding 4-5 mg/l (uneconomical)				
F Excessive foaming or frothing	1	High concentrations of surface active agents (detergents) in aeration basin, possible surfactant resistance to biological degradation	1	Add foam depressants; diffused air flow rate if possible, provide defoam spray, raise solids level

TABLE I (Continued)

G Floating sludge	1 Caused by nitrification - bacteria utilize oxygen contained in the nitrates resulting in the production of gaseous nitrogen which floats the solids	1 Provide scum baffles, more rapid sludge return. If second stage oxidation is not required you may reduce aerator solids and aeration to reduce nitrification
	2 May also be caused by septic sludge	2 Increase rate of removal of activated sludge from final settling tank
H Excessive fluctuating waste strengths and flows associated with weekend vs. weekday usage of recreational facilities, and others		1 Provide an aerated surge tank or basin to equalize flows
		2 Provide some storage in the collection system
		3 Provide increased treatment capacity
		4 Use chemical treatment (coagulation, act carbon) during overloads
5 Not accepted by many states for smaller installations without additional backup treatment facilities to maintain secondary treatment standards.	2 Lesperance, T.W. A generalized approach to Activated Sludge, Parts 1-7, Waterworks and Wastes Engineering, Ruben Donnelly Publishers, New York, N.Y. April - October 1965.	
6 Removes BOD ₅ by conversion to cellular matter, subject to the vagaries of biological treatment.	3 Stewart, M.J. Activated Sludge Process Variations -- The Complete Spectrum, Water and Sewage Works, Pages R -- 241 through R -- 262, Reference Number, 1964.	
7 Large volume of waste sludge to dispose of. This sludge may be difficult to dewater.		

REFERENCES

- 1 Eckenfelder, W.W., Jr. Biological Conversion Processes, Unpublished paper prepared for FWQA Manual on Sewage Treatment processes. 1969.

This outline was prepared by James A. Montgomery, Sanitary Engineer, River Basin Planning, Office of Water Programs, Washington, DC 20242.

ACTIVATED SLUDGE WASTE TREATMENT PROCESS VARIATIONS AND MODIFICATIONS

I INTRODUCTION

A In practice there are three ranges of food-to-microorganism (F/M) ratios where the resultant activated sludge physical quality permit successful continuous plant operation with a minimum of problems. The higher loading range is designated high rate, the intermediate range is conventional, and the lowest loading range is extended aeration. The fourth basic process variation does not require sludge separation for recycle. It operates at the highest loading range and is designated dispersed growth. The characteristics of these process variations are shown graphically in Figure 1.

B While there are four basic process variations to be considered in activated sludge waste treatment, there are many modifications that have been adapted by the design engineer since the first activated sludge waste treatment plant was constructed in the United States about 1920. The purpose of this outline will be to consider these major modifications and their advantages or limitations.

II DISPERSED GROWTH ACTIVATED SLUDGE PROCESS

When true log growth occurs, the number of organisms should double in size every 20 - 60 minutes. This may occur with food levels of 1,000 - 10,000 mg/l as in bacterial culture work. In most waste treatment plants, however, typical air supply and nutrient levels do not support log growth very long and usually for a small percentage of the organism population.

Dispersed growth, therefore, is a basic process variant which is primarily of academic interest. In the presence of a large excess of soluble organic food matter, the microorganisms operate at high energy levels in assimilating this food matter. Settleable suspended solids are not removed from the effluent and returned to aeration for reuse. New cellular matter is formed as fast as it is lost with the effluent. A low solids equilibrium can be maintained without the need for return of sludge.

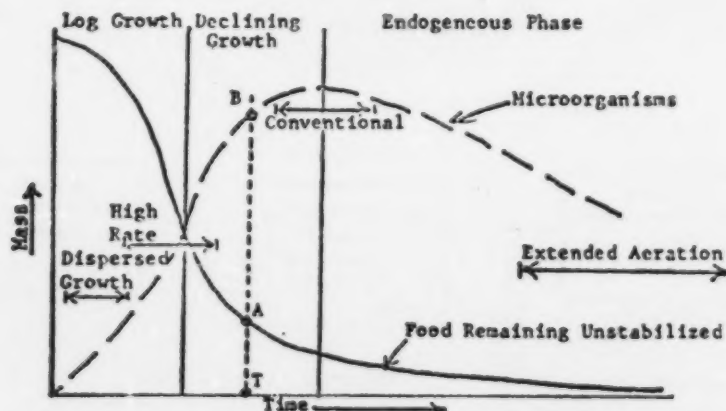


FIGURE 1 Ideal Growth Curve -- Continuous Operation

The dispersed growth activated sludge treatment process utilizes the simple flow arrangement shown in Figure 2. Note that final clarification of the effluent is omitted.

Because of the low BOD_5 removal and high loss of cellular matter in the effluent, the dispersed growth process has limited use. Primary use is for relief of loading for subsequent treatment.

III HIGH RATE OR SHORT TERM ACTIVATED SLUDGE PROCESS MODIFICATIONS

The high rate process operates at high BOD_5 loadings or food-to-microorganisms ratios and has a high cell synthesis rate resulting in maximum production of excess sludge. This generally amounts to about 0.75 pound of sludge produced for every pound of BOD_5 reduced by the process. The high rate process also has the smallest overall oxygen requirement which is approximately 0.45 pounds of oxygen per pound of BOD_5 reduced.

Only a small amount of sludge is recycled to the aeration tank, and the aeration period is kept short. The fraction of oxidizable organic matter removed is in the range of 60 - 70 percent. The process uses a minimum of aeration volume, oxygen and aeration power for the load treated. While the system upsets easily, it returns to usual operating efficiency quickly. Sludge produced usually settles and compacts readily.

Aside from lower BOD_5 removal, its biggest limitations are from high waste sludge production which requires large digestion facilities and results in high sludge disposal costs.

A High Rate or Modified Activated Sludge

High rate or modified activated sludge treatment utilizes the simple aeration tank-final clarifier arrangement which is also standard for conventional treatment. This is shown in Figure 3 below:

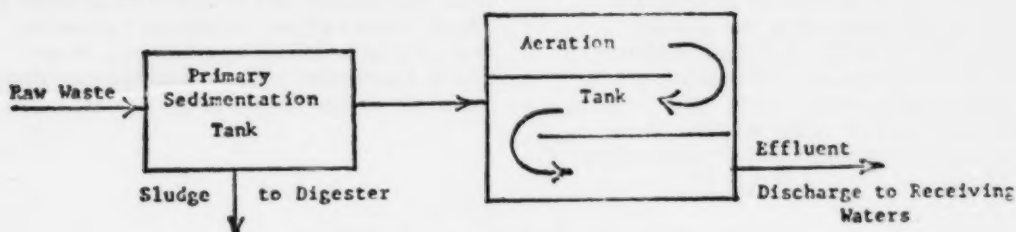


FIGURE 2 DISPERSED GROWTH

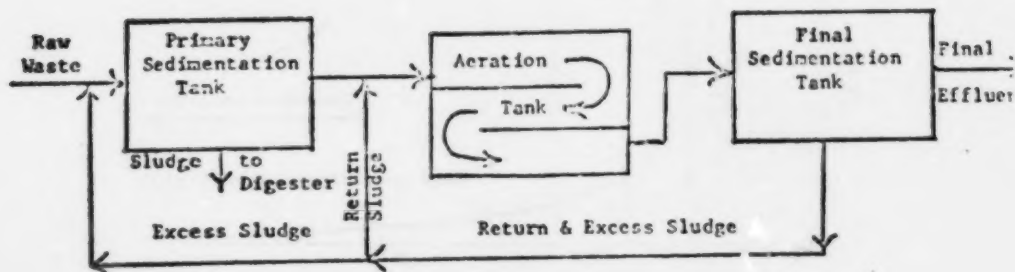


FIGURE 3 High Rate or Modified Aeration

The step loading method of feeding has also been employed with this flowsheet. Primary treatment may be included as shown, or it can be eliminated from the flowsheet if desired.

B Supra-Activation

Supra-activation is a high-load process modification giving a degree of treatment similar to that achieved by modified aeration and using the same structures. It may be used for "roughing" treatment preceding other processes. Patent applications have been made by W.H. Torpey for this process with assignment of the rights to Chicago Pump. The principal advantage of this variation is that for tank loadings of 200 to 800 pounds of BOD₅ per 1000 cubic feet of aeration tank capacity,

the aeration tank required is approximately one-quarter of the size of that required for the Modified Aeration process and approximately one-eleventh of the size required for the Conventional Activated Sludge process.

C Activated Aeration

Figure 4 below shows a modification of the High Rate process that is referred to as activated aeration.

Activated aeration is capable of providing an effluent of intermediate quality at 25% savings in air compression power costs when compared with the straight high rate process. The difficulties of control experienced with high rate treatment are avoided since it is not necessary to recycle active solids through the system. Some reductions in sludge production are also realized.

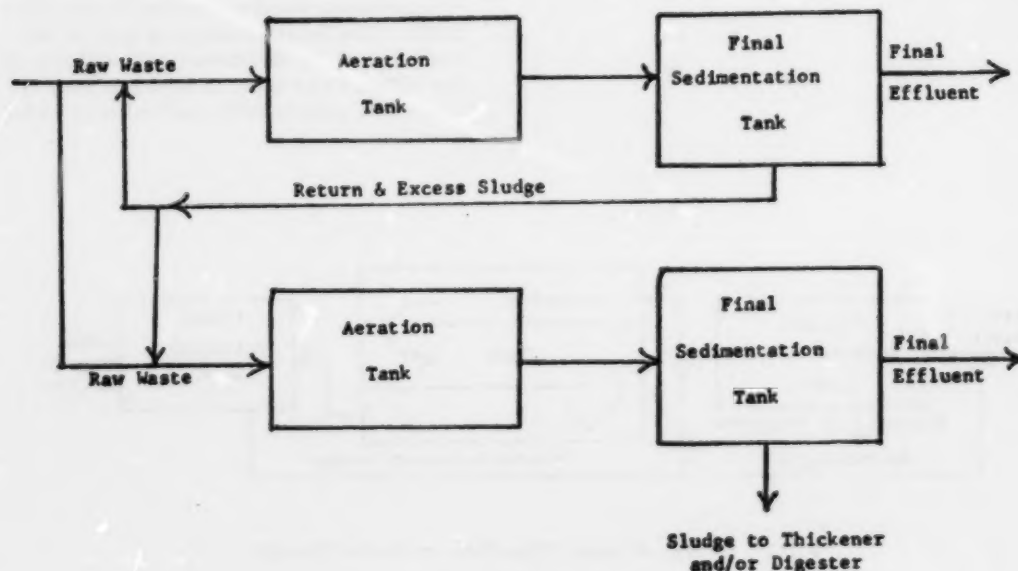


FIGURE 4 Activated Aeration

IV CONVENTIONAL ACTIVATED SLUDGE PROCESS MODIFICATIONS

Conventional operation is the oldest and most commonly used mode of the activated sludge treatment. It is versatile and represents a good compromise among treatment performance, capital, operating and sludge disposal costs for plants of the household variety to the large city plant. Economics and operational control are favored in the large plant facility. Effluent quality will satisfy most government standards. Additional solids, nitrogen, and phosphorus removal may be required in critical situations. Some tradeoff is possible between aeration and sludge disposal cost - more aeration, less net sludge residual.

Any biological process performs better at uniform low loading, non-toxic environment and favorable conditions. Operating control requirements rapidly rise as these criteria depart from the ideal due to design, capacity or loading factors. It is a cause and effect situation. High performance expectancy for a natural process compressed in terms of time and space requires more operational control.

A Conventional Plug-Flow Activated Sludge

The original standard flowsheet uses what we now call plug-flow aeration tank design. These tanks were long rectangular basins with the waste introduced at one end and discharged at the opposite end some distance away.

Figure 5 shows a common version of this modification using series, multi-pass, aeration with return sludge and influent introduced at the tank inlet.

It was believed that this flow arrangement was very desirable since it reduced short circuiting to a minimum, insuring that all of the waste remains under aeration for the maximum period of time.

On the other hand, this kind of flow pattern produces a continually changing environment within the aeration tank. During passage, the available food is being used up while the population of microorganisms at first increases and then decreases. Under these conditions, there is a situation of constantly varying food/microorganism ratio. The BOD_5 loading is high at the head end of the aeration basin and low at the effluent end with an average loading occurring only briefly somewhere during aeration.

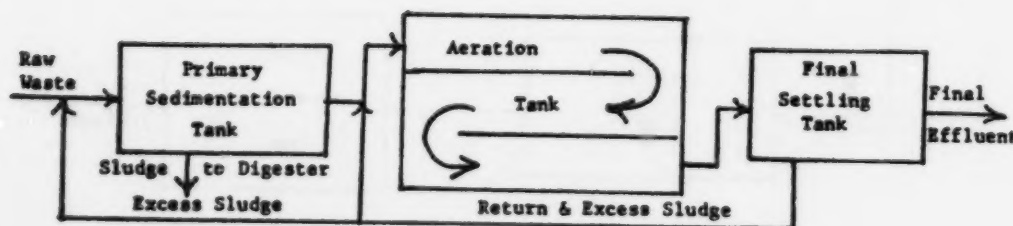


FIGURE 5 Conventional Plug-Flow Activated Sludge

Since loading is continually changing, the environment is forever changing and the relative predominance of the various species of microorganisms continuously change. Equilibrium is never obtained and the system is always out of balance. Under these conditions, the microorganisms work less efficiently than if they are provided with a constant environment.

1 Characteristics

- a Detention time in aeration tank -- 4 to 8 hours.
- b Loading -- 25 to 35 lbs BOD₅ per day per 1000 cu. ft. of aeration tank capacity, or 0.2 to 0.5 pounds BOD₅ per pound of volatile suspended solids (VSS) under aeration.
- c Return sludge rate -- return sludge ratios for this type of system usually maintained between 25 to 50 percent. As the loading increases, solids return should increase.
- d Air introduced uniformly along tank length.
- e Highest organic loading and hence highest oxygen demand at head of aeration tank.

f Waste stabilization proceeds along length of tank -- hence lowest oxygen demand at outlet end of tank.

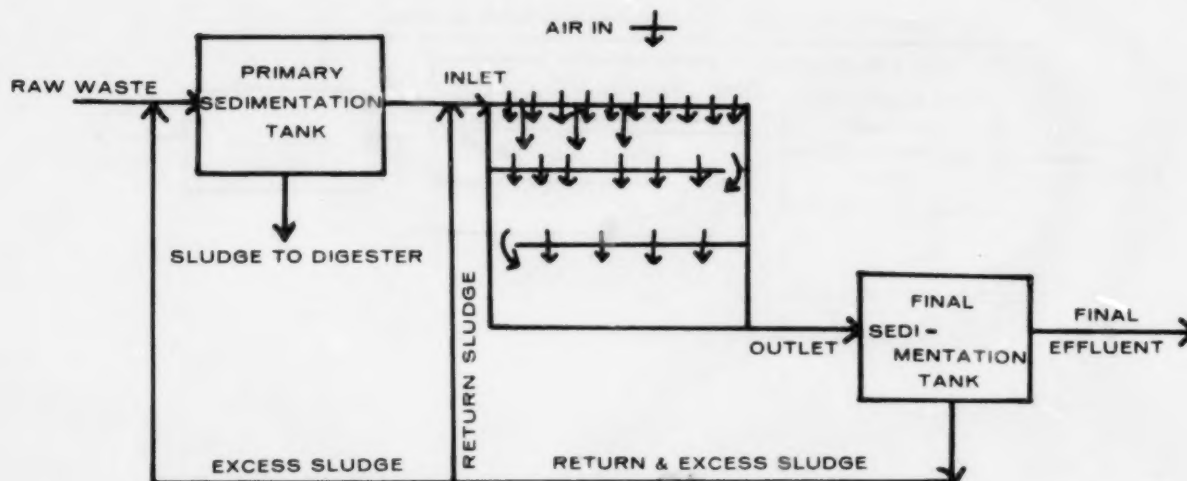
g Excess sludge production - for systems treating domestic wastewater, the volume of excess sludge to be disposed of is usually about 1.5 percent of the influent flow or about 0.5 lbs/lb BOD₅ removed.

h Most process modifications were adapted to improve conditions to make better use of biological stabilization in available space and time.

B Tapered Aeration Activated Sludge

A relatively high initial oxygen demand is normally encountered at the influent end of the aeration tank of a conventional activated sludge treatment plant. As the flow passes down the length of a tank, the oxygen demand of the waste is gradually satisfied and the remaining oxygen demand becomes less and less.

The Tapered Aeration process shown in Figure 6 is designed to supply more oxygen at the head end of the system where the load is highest and then reduce it proportionally with the organic loading along the length of the aeration tank.



- 1 Flow diagram same as Conventional.
- 2 More air introduced at the inlet end of the aerator than in subsequent aerator capacity.
- 3 Results in more efficient use of air and improved aeration power economy.
- 4 Detention times and loadings similar to conventional system -- Tapered Aeration has a volumetric loading of about 35 pounds BOD_5 per day per 1000 cubic feet of aeration tank capacity.

C Step-Aeration Activated Sludge

Another way to even out the oxygen demand in the mixed liquor of the aeration tank is to introduce the waste flow at intervals throughout the length of the tank. This process is termed Step Aeration but might more correctly be termed Step Loading. This system is shown in Figure 7.

If the aerator happened to be divided into four passes, the return sludge usually would be introduced at the inlet of the first pass and flowing through the rest of the passes in series. Sewage may be added in any desired portion at the head end of any or all of the passes. Ordinarily, one-quarter of the primary sewage effluent flow is admitted to Pass B, one-half to Pass C and one-quarter to Pass D. The net result is a better mixed system with more equalization of the load. The advantages claimed for this method of waste loading are: higher BOD_5 removal with shorter detention time, good sludge settling with uniform degree of treatment and more efficient oxygen transfer. This modification is particularly good for wastewaters with high organic loadings providing solids transfer is good. The benefits gained are those obtained in the use of a more completely mixed conventional system with the following characteristics:

- 1 Sewage introduced at various points along length of aeration tank.

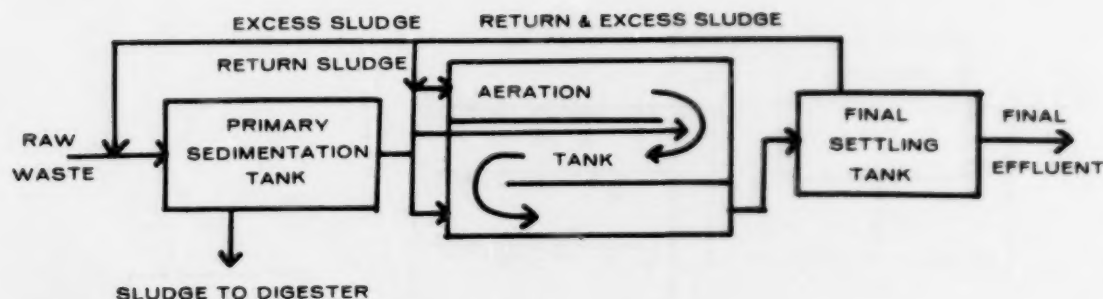


FIGURE 7 STEP AERATION ACTIVATED SLUDGE

- 2 Evens out organic load and also oxygen demand.
- 3 Detention time in aeration tank -- 3 to 4 hours.
- 4 Loading -- 50 to 75 lbs BOD₅ per day per 1000 cu. ft. of aeration tank.
- 5 Return sludge ratio -- 25 to 50%.

D Complete - Mix Activated Sludge

Aeration systems which approach complete mixing are easily obtained by the proper choice of aeration tank shape, method of feeding, and aeration equipment. Figure 8 below shows one possible arrangement. This is more readily obtained in small aerators.

Greater dispersal of the influent and more rapid mixing with the tank contents is desired. Single or multiple point feed and discharge can be used depending on the size and type aeration system provided.

Mechanical aerators, are significantly different from diffusion devices in two respects. First, they produce a higher degree of mixing intensity and, second, they mix in all directions. The flow pattern due to mixing is not only perpendicular to the direction of process flow but also in the same direction and against it. More complete mixing is likely as compared to conventional diffused air placement.

- 1 Incoming sewage and return sludge are completely and instantaneously mixed with the aeration tank contents.
- 2 Results in uniform environment that allows much higher loadings and shorter detention times than with any other modification.
- 3 More likely to dilute shock loads.
- 4 Loading distributed among entire tank contents; better adapted to high load ratios.
- 5 Return sludge ratio - return sludge ratios should be as high as necessary considering sludge characteristics and loading.

E Contact Stabilization

Contact Stabilization uses two separate aeration tanks to provide two stage sludge aeration. The principle is to use first a short (0.5 - 1.0 hour) "contact" stage, during which a major fraction of the applied BOD₅ is transferred from the wastewater to the sludge solids. This occurs by adsorption, absorption, mechanical entrapment, assimilation, filtration, etc. The sludge is then separated from the treated liquid in a clarification step. The sludge moves to a "sludge reaeration" tank with a detention time of 4 - 8 hours, which allows the sludge stabilization to continue. This process is attractive when used on wastewaters containing high proportions of particulate materials such as domestic waste.

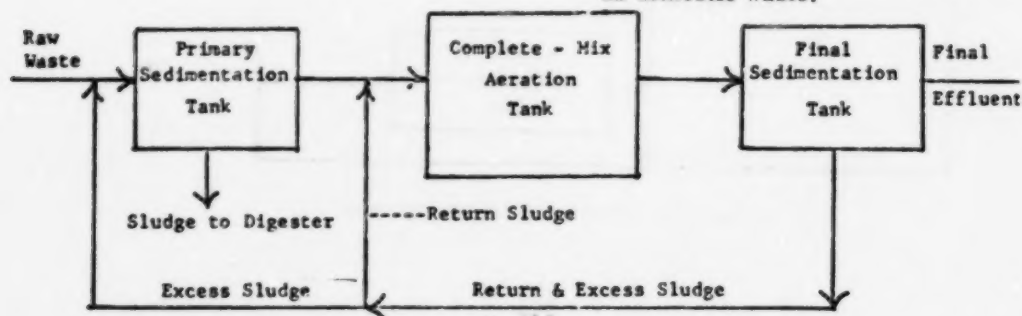


FIGURE 8 Complete - Mix Activated Sludge

The process may be operated to give excellent treatment with low net sludge production. The provision for discharge of the effluent after short period aeration with continued aeration of the more concentrated activated sludge means that total tankage for aeration may be reduced as much as 50% below that for conventional processing. Wastewaters containing predominantly soluble components may not be transferred to the solids phase rapidly enough for good treatment. The contact process tends to recover more rapidly from shock loads.

It is often possible to operate an overloaded Conventional Activated Sludge system as a Contact Stabilization system by changing to step feed and adding the feed later during aeration. Redesigning may only involve changes in the plant piping or relatively minor modification to the aeration tank layout. The settling unit capacity, of course, would have to be increased as flows approach or exceed the original design values.

- 1 Process modification depends on ability of activated sludge to trap colloidal and suspended organic matter.
- 2 Works best with wastes high in colloidal organic matter.
- 3 Reaeration carried out only on settled sludge volume.
- 4 Detention time in initial aeration tank -- 0.5 to 1 hour.
- 5 Detention period in reaeration tank -- 4 to 8 hours.
- 6 Loading -- 35 to 70 lbs, BOD_5 per day per 1000 cu. ft. of combined aeration tank volume.

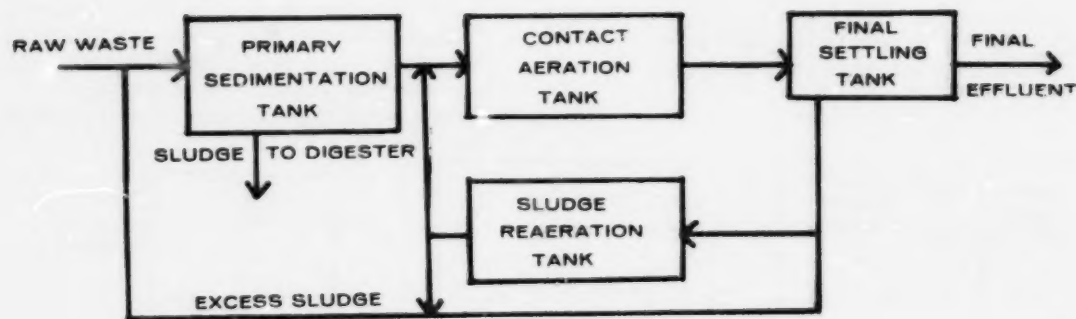


FIGURE 9 CONTACT STABILIZATION

V EXTENDED AERATION ACTIVATED SLUDGE PROCESS MODIFICATIONS

The extended aeration process represented by the two modifications shown in Figures 10 and 11 is designed for low loading as compared with previously discussed activated sludge operating modes. It has also been referred to as the total or complete oxidation process. Solids digestion does limit net sludge production but does not eliminate it. Extended aeration typically operates at very low food-to-microorganism ratios and produces a minimum of residual products. About 0.15 pound of excess sludge is produced for each pound of BOD_5 reduced.

Minimum sludge production is not obtained without penalty. There is maximum oxidation of organic matter to the ultimate end products of carbon-dioxide and water with high power requirements for supplying that oxygen. As loading decreases, more oxygen is used for sludge stabilization.

The unit rate of oxygen utilization, oxygen uptake rate, usually decreases so that a long aeration time is required.

In theory, the rate of sludge build-up is balanced in the extended aeration process by the rate of sludge destruction. The process can be operated in a balanced state, but the ultimate plant effluent discharge quality will be lowered with the loss of incompletely digested solids via the effluent.

Where a plant is fully loaded and a highly polished effluent is required, it will be necessary that excess sludge be wasted at intervals of one to two weeks. The surplus sludge may be discharged without offensive odors, for direct drying on open drying beds, worked into soils or may be diverted to a sludge storage tank and accumulated for ultimate disposal on restricted areas. Cold weather operation usually shows poor sludge stabilization and settling. Generous holding tankage is required.

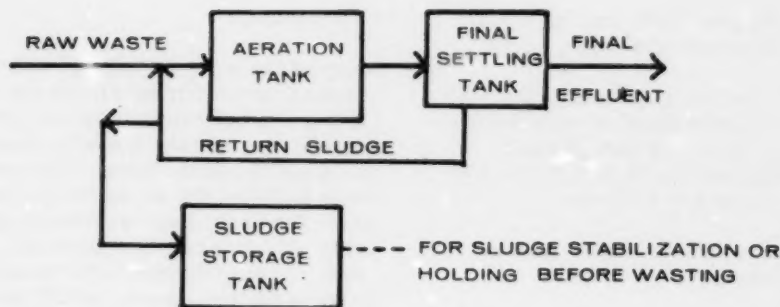


FIGURE 10 EXTENDED AERATION PACKAGE TREATMENT PLANT

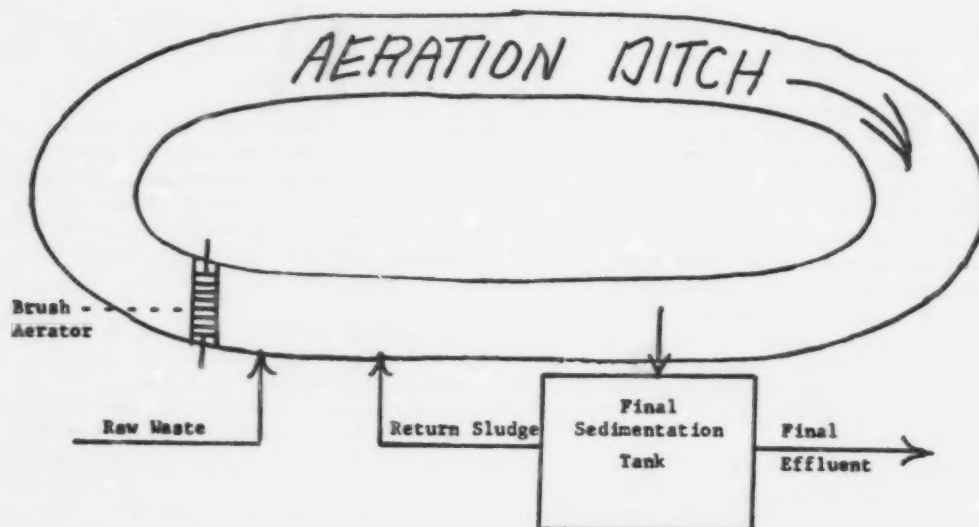


FIGURE 11 Extended Aeration Oxidation Ditch

- 1 Usually smaller package type plants. Economics limit these to relatively small sizes (up to 0.5 mgd capacity). Used for small communities, trailer courts, motels, etc.
- 2 Long aeration period (24 hours) results in aerobic digestion of solids.
- 3 Designed for no sludge wasting, but will always have slow buildup of inert solids that will be lost in effluent. Some sludge control and wastage is necessary to obtain high quality effluents.
- 4 While screening is desirable, primary sedimentation may be omitted.
- 5 Sludge disposal costs are relatively low; but large aeration volume and aeration power requirements are encountered.
- 6 Extended aeration may require more than double the unit oxygen requirement of the conventional process. As much as 1.8 pound oxygen per pound BOD_5 reduced may be used by extended aeration while process with separate solids removal may use about 0.4 - 0.8 pound oxygen per pound BOD_5 reduced.

- 7 High effluent nitrification causes frequent problems with the final clarification especially when scum control is omitted on the final clarifier.

VI SUMMARY

Many of the activated sludge waste treatment process modifications discussed in this outline are not really separate processes in themselves, but are actually operational modes of the same thing. The major differences between them involve variations in waste loadings, food-to-microorganisms ratios and in-plant flow patterns. Most waste treatment plants are hybrids of two or more of the process modifications discussed. Good design practices provide the operator with the capability to change plant operational characteristics as may be advantageous depending on influent nature concentration and flow pattern.

Table 1, which follows, lists the typical operational characteristics and design criteria for the major activated sludge waste treatment modifications considered in this outline.

TABLE 1. OPERATIONAL CHARACTERISTICS OF ACTIVATED SLUDGE WASTE TREATMENT MODIFICATIONS

Name of Process Modification	MGD-Plant Design Flow	Plant Design lb BOD ₅ /Day	Aerator Loading (lbs BOD ₅ per day per 1000 cu. ft.)	Aeration Period in Hours (based on design flow)	Min. Air Requirements cu. ft. lb BOD ₅	MLSS/lb BOD ₅ Ratio	Return Sludge Rate - (percent of design flow)	Detention Period Final Settling Tanks (hours)	Surface Settling Rate (GPD/sq. ft.)	BOD ₅ Removal (percentage)
Conventional AS	To 0.5 0.5 - 1.5 1.5 up	To 1000 1000 - 3000 3000 up	30 30 - 40 40	7.5 7.5 - 6.0 6.0	1500	2/1 to 4/1	15 - 75 Ave. 30	3.0 2.5 2.0	600 700 800	95 *
Modified or "High Rate"	To 0.5 0.5 - 1.5 1.5 up	2000 up	100	2.5 up	400 - 1500	1/1 (or less)	10 - 50 Ave. 20	3.0 2.5 2.0	600 700 800	60 - 75
Step Aeration	0.5 - 1.5 1.5 up	1000 - 3000 3000 up	30 - 50 50	7.5 - 5.0 5.0	1500	2/1 to 5/1	20 - 75 Ave. 50	2.5 2.0	700 800	90 - 95
Contact Stabilization	To 0.5 0.5 - 1.5 1.5 up	To 1000 1000 - 3000 3000 up	30 30 - 50 50	3.0 3.0 - 2.0 1.5 - 2.0	1500	2/1 to 5/1	50 - 150 Ave. 100	3.6 3.0 2.5	500 600 700	85 - 90
Extended Aeration	To 0.05 0.05-0.15 0.15 up	All	12.5	24	2000	10/1 to 20/1	30 - 200 Ave. 100	4.0 3.6 3.0	300 300 600	75 - 85

* Aeration Period in Contact Zone which represents 30 - 35 percent of the total aeration capacity.

Table 2 groups the activated sludge process modifications according to waste loadings.

TABLE 1

WASTE LOADING CHARACTERISTICS
OF ACTIVATED SLUDGE TREATMENT
PROCESSES

1. High Rate AS Process Variations
(Waste Loading > 1.0 lbs COD/lb MLVSS/day

Dispersed Growth
High Rate
Modified Aeration
Supra Activation
Activated Aeration
2. Conventional AS Process Variations
(Waste Loading 0.2 to 1.0 lbs COD/lb
MLVSS/day)

Complete Mix
Plug Flow
Tapered Aeration
Step Aeration
Contact Stabilization
3. (Waste Loading < 0.2 lb COD/lb MLVSS day)

Extended Aeration
Oxidation Ditch

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- 1 Eckenfelder, W.W., Jr. Biological Conversion Process, Unpublished paper prepared for FWQA manual on sewage treatment processes. 1969.
- 2 Lesperance, T.W. A Generalized Approach to Activated Sludge, Parts 1-7, Waterworks and Wastes Engineering, Ruben Donnelly Publishers, New York. April-October 1965.
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This outline was prepared by James A. Montgomery, Sanitary Engineer, River Basin Planning, OWP, Washington, DC 20242.

PHYSICAL-CHEMICAL TREATMENT OVERVIEW

I INTRODUCTION

A Historically biological treatment has been the first (often the only) consideration for municipal wastewater renovation. To work, this system must be engineered to favor environmental control of natural processes. Viable organisms, living space and time on a continuing basis are essential. Today's wastewaters frequently are incompatible with smooth functioning of biological processes.

- 1 Land, equipment, manpower, and time are costly.
- 2 If all other items are favorable, natural processes may be slow to adapt to changes such as:
 - a Discontinuous or nonuniform flow
 - b Qualitative changes in available food
 - c Rapid changes in concentration or condition
- 3 Control is difficult because of the lag time between cause and effect.
- 4 Certain influent components may be relatively inert under treatment conditions.
- 5 Significant amounts of certain waste discharges may kill the working organisms.
- 6 Certain substances are not readily removed because of solubility, poor transfer to solids or recycle.

B Physical-chemical treatment alternatives for secondary treatment have been considered for many years. Applications have been rare for municipal wastewaters except as supplementary treatment. Active testing and documentation of plant scale operations is relatively recent but certain attractive possibilities are apparent:

- 1 Facilities costs may be decreased.
- 2 The process may be designed for removal of specific contaminants and a desired effluent quality.
- 3 Operational control adjustment provides a high degree of treatment versatility.
- 4 Start/stop operations or wide flow variations are more readily accommodated.
- 5 Control is more feasible and automation potential improved because of decreased process lag time. The process is less affected by toxic conditions.

C This outline considers physical-chemical treatment from the building block or unit operations standpoint. Certain combinations of them are attractive for process control. This is not intended as a review of all possibilities in physical-chemical treatment. Certain selected examples are presented for orientation purposes.

II CHEMICAL UNIT PROCESSES

A Coagulation - Precipitation

Coagulation is a process that destabilizes fine particulate suspensions to encourage aggregate formation and favor solids-liquid separation. Chemical precipitation is a process favoring conversion of certain dissolved components into insoluble aggregates.

- 1 Both processes are accomplished by the addition of certain chemicals in suitable amounts.
- 2 For example wastewater renovation includes iron aluminum or lime addition to coagulate silt and organic particulates, and to precipitate phosphate phosphorus.

- 3 A rapid mix is employed to insure contact of added chemicals and wastewater (coagulation). Following this a slow mix is employed to increase the size and separability of the initially formed aggregates (flocculation). A flocculating aid may or may not be used. A coagulation step usually improves the clarity of the product water. Both solids concentration and drainability of the solids concentrate are generally improved.
- B Hydrolysis is a unit process involving the addition of water to some chemical entity or complex leading to the formation of smaller less complex breakdown products.
- 1 The process of decay is intimately related to hydrolysis reactions. A protein may add water and split into smaller components such as peptides, and amino acids. The amino acid may separate into an acid and ammonia by additional hydrolysis. Usually these reactions in nature are hastened by some enzyme (a natural catalyst produced by living organisms).
 - 2 Free carbon dioxide gas dissolved in water may react with water to form carbonic acid.
 - 3 Calcium carbonate is relatively insoluble in water. It may hydrolyze to form alkaline calcium hydroxide or react with hydrolyzed carbon dioxide to form soluble calcium bicarbonate.
- C Neutralization is the chemical combination of an acid and an alkaline material to form a salt and water. This is opposite in relation to an hydrolysis reaction.
- 1 Calcium hydroxide plus carbonic acid react to form calcium carbonate (B 2 & 3). If carbonic acid is in excess calcium bicarbonate is formed.
 - 2 The equilibrium between carbon dioxide bicarbonates and carbonates form a natural buffering system to resist changes due to addition of acid or alkaline materials. Addition of carbonic acid causes solution of deposited carbonates to form bicarbonates. Addition of alkalis causes deposition of carbonates. As long as the alkaline bicarbonates are in excess the water tends to remain near a pH range acceptable for living organisms.
- 3 Excesses of acid or alkaline chemicals may be neutralized at the source by appropriate addition and mixing of the opposite reactant such as lime addition to neutralize acid mine drainage.
- D Oxidation is a primary consideration in stabilization of waste components. Any substance undergoes oxidation when oxygen is added or hydrogen is removed. The opposite reaction is considered reduction. Both reactions occur simultaneously, i.e., when a waste component is oxidized an equivalent amount of oxygen or other oxidizing agent must be reduced.
- 1 Oxygen from the air or in dissolved form in the water is the major oxidizing agent. Organic carbon compounds in waste material react with oxygen by biological or chemical reaction to form carbon dioxide and water.
 - 2 Other oxidizing agents such as chlorine permanganates, ozone, have higher oxidation potential and are used for special purposes.
- E Disinfection is defined as a process of killing pathogenic bacteria (as distinguished from sterilization where all living organisms are killed).
- 1 Chlorination is the most common disinfecting method used today. Free hypochlorous acid is the most potent form of chlorine available as a disinfecting agent. Monochloramine probably is the most likely and strongest disinfectant available in wastewater chlorination (at mid range pH values).
 - 2 Ozone is receiving increasing attention as a disinfectant for odor control and as an oxidant.

III SOLIDS-LIQUID SEPARATIONS

Solids-liquid separation is a physical unit operation used more commonly than any other process in both biological and physical-chemical wastewater treatment.

A Gravity sedimentation employs an enlargement of the channel or basin to decrease flow velocity to a point where solids aggregates that are heavier than water will settle and be removed as a sludge or solids concentrate. Particle settling rate depends upon the shape, size, and surface area of the aggregate and relative difference in density of the particle and suspending liquid. Separation depends upon liquid depth, internal currents or mixing, and compactability of the solids concentrate.

- 1 Gravity separation may range from grit separation wherein high density particles with little water holding capacity and high settling rate are separated to those in which very low settling rates are inherent because the aggregates have a low relative difference in density, a high frictional resistance, and poor compactability (such as for secondary sludges).
- 2 Solids produced from untreated wastewaters (such as in primary treatment) usually are intermediate in settling rate.
- 3 Coagulation with suitable additives usually means separation of more items to a higher degree. Decreased water holding capacity and better drainability of the solids concentrate are common.

B Flootation is a unit operation wherein immiscible solids or liquids having a density less than that of the suspending liquid are separated. Rise rate is controlled by the same factors that are important in settling rate.

- 1 Flootation invariably occurs in gravity separation among those materials having a lower density than the dispersing liquid.

- 2 Additives may be used to convert certain aggregates into a floatable concentrate by producing a froth of gas bubbles attached to solids or liquids. Density of the combination is reduced.

C Screening is a unit operation in which some barrier is employed to restrict passage of any particle larger than the size of the barrier openings. Screening is used for separation of larger particles. Microstraining is the term employed when the openings approach 20 to 60 microns.

- 1 Usually the trapped material becomes its own barrier after initial deposition but vibration, rotation, pressure sprays or mechanical wiping may be employed to clean the surface.
- 2 Submerged rotating drums, vertical or inclined racks, vibrating platforms, moving links, belts or other means of screen support are used.
- 3 Bar racks, grid systems, wire or fabric cloth, slots or other configurations are employed for screening.

D Surface filtration is a term employed for liquid solids separation where the removed material accumulates at the interface. This operation is simple and positive but is subject to plugging. It is applicable for separations of fine particulates down to the ultrafiltration range where plastic membranes are employed to obtain pore openings less than 1 micron.

- 1 Filtration media include synthetic or natural fiber cloth, glass cloth, modified cellulose, synthetic plastic membranes, diatomaceous earths, etc.
- 2 Pressure drop across the interface may be large for small pore surface filtration media. Static head, pumping pressure, selective wetting, and capillary action, may be used to encourage liquid passage.

- 3 Elaborate support mechanisms may be employed to meet the low volume/unit area and high pressure differential situations of fine pore media.
- E Bed filtration is essentially the same as surface filtration. Pressure drop at the surface is similar but base exchange, biological stabilization, complex formation and other conversions within the bed may be greater. The filter surface normally can be cleaned and regraded by backwashing the expanded bed.
- 1 Sand, Anthracite coal, soil and other granular materials may be used for bed filtration.
 - 2 Commonly relatively coarse media on the bottom are graded upward to a relatively fine granular material on top. Single media bed filtration includes different sizes of media of the same density.
 - 3 Multi media bed filtration may have a gravel sand mixture on the bottom with anthracite or other media over it. The anthracite of a larger grain size than the sand will be hydraulically graded over the top because it is less dense than the fine sand. The larger media permits more penetration into the bed for flocculation and storage and decreases the pressure drop at the surface zone.
- F Adsorption is a unit operation involving a tendency for some types of materials to accumulate at or near the interface zone of another.
- 1 The adsorption of soluble organic materials on activated carbon surfaces is used for both water and wastewater treatment.

- 2 Powdered or granular activated carbon may be used.
- 3 The process favors efficient removal of dissolved organics.

IV PHYSICAL-CHEMICAL OPERATIONS THAT APPEAR MOST ATTRACTIVE CURRENTLY INCLUDE:

- A Some form of coagulation and flocculation with lime alum or iron to destabilize fine suspended particles and to precipitate phosphates and certain metallic components.
- B Clarification including gravity sedimentation followed by bed filtration to produce a low solids product water.
- C Activated carbon adsorption of soluble organics in the clarified product water.
- D Disinfection of the product water.

Centrifugation, ion exchange, distillation electrodialysis, gas-liquid interchange and many other possible choices were not considered primarily because of space and time limitations.

ACKNOWLEDGEMENT:

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This outline was prepared by F. J. Ludzack, Chemist, National Training Center, EPA, OWP, Cincinnati, OH 45226.

FUNDAMENTALS OF TRICKLING FILTRATION WASTE TREATMENT

I INTRODUCTION

Trickling filters are not filters at all, but basically only a pile of rocks providing surface area upon which slime organisms grow. These organisms feed on the dissolved food matter contained in the waste effluent applied to the filter. When too thick a slime growth accumulates, anaerobic conditions develop at the media surface. A natural mechanism for cleaning the filter occurs with the periodic "sloughing" of the slime layer from the surface of the filter media. Solids that are sloughed off are collected by final clarification of the filter effluent.

As waste passes through the filter, nutrients and oxygen are transferred to the slimes, where assimilation occurs, and by-products and CO_2 are transferred out of the slime into the flowing liquid. As oxygen diffuses into the biological film, it is consumed by microbial respiration so that a defined depth of aerobic activity is developed. Slime below this depth is anaerobic.

In a manner analogous to activated sludge such as the contact stabilization mode, BOD removal through a trickling filter is related to the available biological slime surface, its activity and to the time of contact of waste with that surface.

II TRICKLING FILTER COMPONENTS AND THEIR FUNCTIONS

A Distribution - rotary or fixed nozzle

Intermittent waste application, wets all media surfaces, applies effluent uniformly.

B Media or Packing

Supports slime growth, and intimate contact of slime - wastewater - air.

- 1 Conventional filters contain 2-1/2 - 4 inch rock packing and vary in depth from 3 - 8 feet. Hydraulic loadings to the filter of 0.5 gpm/ft² will yield BOD removal efficiencies up to 85%.
- 2 Plastic packings, such as Surfpac, are employed in depths up to 40 feet with hydraulic loadings as high as 4.0 gpm/ft². Depending on the hydraulic loading and depth of the filter, BOD removal efficiencies as high as 90% have been attained on strong wastes.

C Underdrainage System

Collects and conveys effluent, admits or draws off air, supports filter media.

D Secondary Clarifier

Provides separation of agglomerated solids and sloughed slime growths from final effluent. Final clarifier overflow rate varies between 800-1000 gallons per day per square foot (gpd/sq ft).

III ADVANTAGES AND LIMITATIONS OF THE TRICKLING FILTRATION PROCESS

A Advantages

- 1 Relatively high nitrifying effect upon effluent
- 2 Low operating cost
- 3 Ability to function under extreme weather conditions
- 4 Good efficiency in BOD_5 removal
- 5 Good efficiency in suspended solids removal
- 6 More complex biota than for activated sludge

B Limitations

- 1 High head losses
- 2 Odor and fly nuisances
- 3 Large land area required
- 4 High initial construction cost
- 5 Head losses may require pumping
- 6 Forced ventilation may be necessary

IV CLASSIFICATION OF TRICKLING FILTERS

A Low Rate or Standard Trickling Filters

- 1 Hydraulic loading
1.1 - 4.4 million gallon per acre per day (mgad) 25 - 100 gpd/sq ft
- 2 Organic loading
220 - 1,100 lbs BOD₅/acre-ft/day
5 - 25 lbs BOD₅/1000 cu ft
- 3 Recirculation - usually not
- 4 Filter depth - 5 - 10 ft (ave. 7')

Most of the very early filters were of this type.

B High Rate Trickling Filters

- 1 Hydraulic loading
8.7 - 44.0 mgad
200 - 1000 gpd/sq ft
- 2 Organic loading
1,100 - 13,000 lbs BOD₅/acre - ft/day
25 - 300 lbs BOD₅/1000 cu ft
- 3 Recirculation - normally provided
- 4 Filter depth - 3-7 ft (ave. 5')

Most of the filters constructed in recent years have been high-rate filters.

These filters were built with various depths, and organic loadings.

The performance of biological treatment units of this type is dependent upon the volume of ACTIVE growth present in and on the filter media. The size of the filter and the type of filter media determine the amount of space available for the growth of the biological slime mass.

The rate of application of the waste influences the amount of growth that will develop. The two types of loading (i.e. organic loading and the volumetric or hydraulic loading) have opposite effects. The greater the amount of available organic matter, the greater the food supply and expected growth. Recirculation increases trickling filter efficiency. High dosage rates however increase scour, dislodge slime growth, and reduce the volume of active growth present in and on the filter media. It is noted that organic loading has greater influence on trickling filter efficiency than hydraulic loading.

C Super Rate or Roughing Filters

- 1 Hydraulic loading - up to 1000 mgad
- 2 Organic loading - (see comment noted below)
- 3 Recirculation - normally provided
- 4 Filter depth - up to 40 feet using manufactured plastic filter media instead of rock or stone

This process is usually associated primarily with treatment of industrial wastes.

In recent filter design, organic loadings greater than those listed above for the high-rate filters have been applied. This is particularly true when manufactured filter media is used. Presumably the ratio of the useful surface area of the media to the volume of the media is greater, resulting in higher efficiency of BOD₅ removal per unit volume of filter.

Manufactured filter media provide a much greater surface area for slime growth per unit volume than rock or slag. Greater ventilation possibilities are inherent.

V DESIGN CONSIDERATIONS FOR TRICKLING FILTRATION SYSTEMS

A Common Flow Diagrams

Figures 1 and 2 show the more common flow diagrams and operational variations for recirculation of solids and effluents associated with trickling filtration waste treatment.

B Factors in Trickling Filter Design

It appears that the efficiency of a trickling filter is dependent upon all or some of the following variables:

- 1 Composition and characteristics of the waste
- 2 Organic loading
- 3 Pretreatment by sedimentation or other processes
- 4 Hydraulic loading; recirculation ratio and system.
- 5 Filter bed characteristics; volume, area, and depth
- 6 Type of filter media selected
- 7 Aeration or forced ventilation
- 8 Wastewater and air temperature

C Pretreatment Requirements

- 1 The BOD applied to the filter should generally not exceed 500 mg/l in order to insure aerobic conditions. Recirculation should be employed when wastes have BOD₅ values much in excess of this value.

- 2 When a filter packing with a high specific surface is used, a minimum hydraulic loading is essential to avoid the accumulation of excessive biological growths and resulting filter ponding.
- 3 The pH of the wastewater applied to the filter should be such that the excess alkalinity or acidity is neutralized in the top few feet of the filter media. Excessive acidity or alkalinity can frequently be neutralized by recirculation of filter effluent.

D Effects of Recirculation

- 1 Part of the organic matter in the raw waste feed is brought into contact with the slime organisms more than once.
- 2 High concentration wastewaters are diluted before contact.
- 3 Recirculated effluent contains active microorganisms not found in such quantity in raw waste, thus providing seed continuously.
- 4 Diurnal organic waste loadings are distributed more evenly.
- 5 The continuation of waste application to the filter during periods of low flows (night time) precludes long detention periods which may result in septicity. Stale sewage is freshened. Slimes do not dry out.
- 6 Increased hydraulic loading through recirculation improves uniformity of waste distribution, increases sloughing, and reduces clogging tendencies.
- 7 Higher velocities and continual scouring also produces conditions less favorable for the growth of filter flies.
- 8 Continual seeding with active slime organisms and enzymes stimulates hydrolysis and oxidation and increase the rate of biochemical stabilization of the waste.

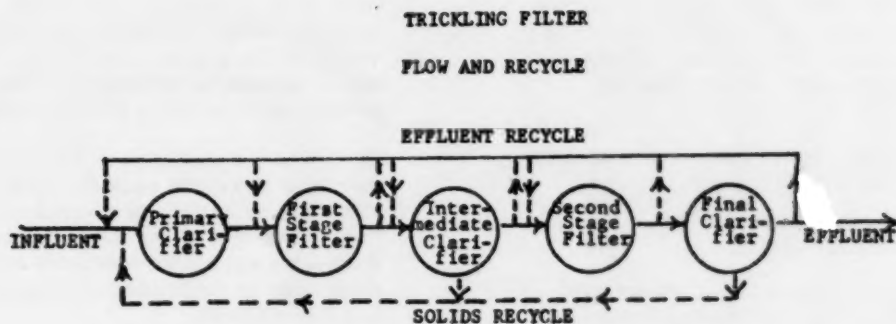


Figure 1

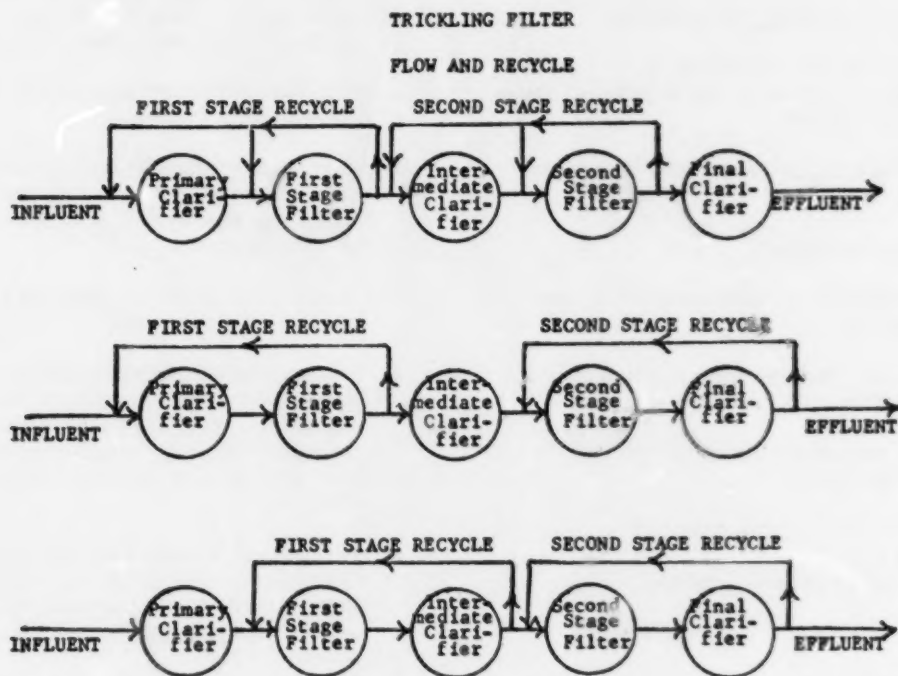


Figure 2

- 9 Recirculation will increase operating costs because of the necessary pumping of the return effluent.
- 10 Wastewater temperatures may be reduced as a result of the number of passes of the liquid through the filter. During cold weather, this may result in decreased biochemical activity and reduced efficiency of treatment provided.

VI FILTER OPERATION AND MAINTENANCE

A Maintenance of Equipment

Requirements vary somewhat with each piece of equipment. Specific instructions should be obtained from the manufacturer. Common requirements usually include the following:

1 Top bearing

- a Add grease monthly
- b Remove, inspect, clean, and lubricate with new grease once each year.

2 Lower bearing

- a Ball bearing--check oil level monthly
- b Roller bearing--add oil or grease monthly
- c Mercury seal--drain, inspect, and check quantity once each year. Add mercury when necessary. Check as needed under contingency conditions.
- d Oil seal--check and add oil as required. Drain, inspect, and replace oil at least once each year and seasonally where required.

- 3 Guy rods--in cold weather it may be necessary to loosen guy rods in order to prevent arms from being raised at the outer end. In warm weather tighten guy rods to prevent arms from dragging on the stone.

- 4 Freezing--when there is danger of freezing, gates at ends of arms may be left partly open to drain the distributor. This is not required where distributors operate continuously.
- 5 Closing down--whenever it is necessary to shut the distributor off for any extended length of time, the drain valve in the base ell should be opened.

B Plugging of Filters--"Ponding" of filters may occur if prolific growths develop completely filling voids between the rocks or if leaves, trash, or plastics accumulate in the bed. One or more of the following methods may be used to reduce or eliminate plugging:

- 1 Flush the surface of the filter with a fire hose, simultaneously loosening rock with a bar as the jet is applied.
- 2 Rake or fork the surface.
- 3 Stop the distributor over affected areas, and allow the flow of sewage to wash down growths and sludge. This is applicable if bed is not completely sealed.
- 4 Apply heavy doses of chlorine or chlorinated lime in the filter influent in concentrations up to five mg/l residual for periods of two to four hours at intervals of two or three days. This should be done at night when flow is light and chlorine requirement is low.
- 5 Flood the filter and allow to stand 24 hours.
- 6 Dry the filter by taking it out of service for 12 to 48 hours and exposing it to sunlight. This should be done only if other units are available to provide adequate treatment capacity.
- 7 Under no condition should heavy equipment be allowed on the filter surface. The weight will cause damage to the walls, crust filter aggregate and cause damage to underdrain systems, cause further ponding, and require extensive

repairs and replacements. Heavy equipment must be supported by planking to distribute load.

- 8 In cold climates, keep the surface of the filters sufficiently free of snow to permit operation of rotary distributors. Leaves and other wind-blown material should not be allowed on the filter. Removal of trees from areas nearby may be necessary. Promptly remove surface paper leaves plastic-wind-blown or water carried.

C Filter Flies - Breeding in filters is minimized where there is continuous heavy uniform application of liquor to the stone and wall surfaces, provided sludges do not accumulate. Pupae and larvae develop under favorable operating conditions, but in high rate filter units they are continuously washed into the final settling tank. In the standard filter, particularly with intermittent operation, flies may become a nuisance. The distribution from center to outside walls. One or more of the following control measures may be utilized.

- 1 Vigorous hosing of inside filter walls.
- 2 Flooding the filter. The filter flies seem to prefer a damp but not a wet environment. The filter should be flooded for 24 hours at intervals of ten days to two weeks depending upon the hatching cycle. Filter efficiency may decrease temporarily following such flooding, but it will be regained in a reasonable length of time.
- 3 Cut all grass and weeds around filters.
- 4 Use of DDT--washing or spraying filter walls with a five percent solution DDT insecticide in kerosene will effectively kill all contacted adult flies. This should be started early in the season and be repeated each six weeks. This procedure has been used successfully to reduce flies below the nuisance level and has had no deleterious effect upon the operation of the filter. Check use regulations first.

D Control of Odor - Odors from filters are due to undesirable growths, sludging, and anaerobic decomposition. Odors can be eliminated by preventing such conditions from developing. The following methods are recommended:

- 1 Where the sewer system is extensive or grades flat, sewage may undergo decomposition before reaching the plant. Aeration or chlorination of sewage in the upper part of the collection system will freshen the raw sewage plant influent and reduce odors. The trickling filter influent may also be aerated to oxidize organic overloads, eliminating anaerobic conditions within the filter which result in hydrogen sulfide production and odors.
- 2 Recirculation of filter effluent may also be used to promote aerobic conditions.
- 3 Promote good housekeeping and maintain a washdown schedule to aid plant cleanliness.

E Records of Operation

Plant records should include the following:

- 1 Rate of recirculation to filter, if any, and source of recirculated material.
- 2 Record of cleaning spray or distributor nozzles.
- 3 Record of mechanical maintenance of filter distributor and appurtenant mechanisms.
- 4 Remarks covering any unusual condition or operation correction of ponding, fly breeding, odor control, snail infestation, etc., as effected by chlorine application, flooding, washing, etc.
- 5 Complete laboratory analysis as required.

ACKNOWLEDGEMENT:

Portions of this outline were taken from a previous outline prepared by Quintin B. Graves, Professor of Civil Engineering, School of Civil Engineering, Oklahoma State University, Stillwater, Oklahoma.

This outline was prepared by James A. Montgomery, Sanitary Engineer, River Basin Planning, Office of Water Programs, Washington, DC 20242.

THE DESIGN OF TRICKLING FILTRATION SYSTEMS

I INTRODUCTION

A The Future Outlook for Trickling Filtration Waste Treatment

- 1 Larger cities are turning more and more towards activated sludge waste treatment systems as they realize the limitations of trickling filtration in satisfying future water quality standards. When competent operation and steady-state waste flow conditions are provided, activated sludge will generally produce a higher quality effluent.
- 2 Trickling filtration systems will continue to be designed for the smaller cities where full-time operation is not provided. Trickling filters will normally operate at 80 to 90 percent BOD_5 removal efficiency. Their effluent is expected to be somewhat turbid as compared to activated sludge effluent in which 90 to 95 percent BOD_5 removal is achieved.
- 3 Trickling filtration units will also continue to be utilized in treatment plant expansions as "roughing filters" to equalize and partially reduce high organic waste flows for further waste treatment processes.

B Design Methods to be Considered in this Outline

- 1 "Ten States Standards"--general requirements
- 2 Conventional Design Method
- 3 National Research Council (NRC) Formula
- 4 Eckenfelder Formula
- 5 Galler -- Gotaas Formula

II "TEN STATES STANDARDS"

The Great Lakes - Upper Mississippi River Board of State Sanitary Engineers has formulated policies for the review and approval of plans and specifications for sewage collection and treatment facilities. Their publication, Recommended Standards For Sewage Works commonly referred to as "The Ten States Standards," is currently used by most state water pollution control agencies as a guide for accepted design practices.

This publication may be obtained from the Health Education Service, Post Office Box 7283, Albany, New York 12224. The cost is \$1.00 per copy. TABLE 1 which follows, outlines the more important general requirements for the design of trickling filtration systems contained in this publication:

III CONVENTIONAL DESIGN METHOD

Trickling filtration systems may be classified as "Low Rate" or "High Rate" filters according to their organic and hydraulic loadings. Accepted design ranges for each class of filters are given in TABLE 2. Examples showing how this information may be used to design each class of filters will now be considered.

A Design of Low-Rate Trickling Filter

Example 1

Given:

Sewage Flow Rate (Q) = 10 mgd

BOD_5 in Raw Waste = 200 ppm

BOD_5 Removal in Primary Settling Tank = 30%

Problem:

Design a filter system and check for acceptability

TABLE 1
TRICKLING FILTER DESIGN - 10 STATES STANDARDS

Point Under Review	Standard	Reference
Does a check of the hydraulic factors involving distribution show these to be satisfactory? For rotary type there should be 24" minimum head between low level in siphon and center of arms.	yes	71.23
Is the apparatus or system for distribution one which normally results in uniform distribution of sewage over the filter bed surface?	yes	71.21
Is the clearance between the surface of the filter and the distribution arm of the rotary distributor satisfactory?	6" min.	71.24
Do the specifications describe satisfactory media material?	yes	71.31
Is the size of media satisfactory?	yes	71.33
What is minimum depth of media above the underdrains?	5 ft.	71.32
What is maximum depth of filter media?	7 ft.	71.32
Do specifications require that the media be laid in such a manner as to minimize abrasion?	yes	71.334
Do specifications require that media be hand laid for the first 12" above the underdrains?	yes	71.334
Do the underdrains cover the entire floor of the filter?	yes	71.41
Is the unsubmerged gross combined area of the inlet openings into the underdrains satisfactory?	15% of surface area of filter	71.41
Is the slope of the underdrains satisfactory?	1% min.	71.42
Is the velocity in effluent channels at average daily rate of application satisfactory?	2 ft/sec min.	71.42
Is provision made for flushing underdrains? For small filters a peripheral head channel is acceptable.	yes	71.43
Is inspection provided for?	yes	71.43
Are the underdrains and effluent pipe designed to provide free passage of air?	yes	71.44
Is the size of the underdrains satisfactory? No more than 50% of the cross sectional area should be submerged under design loading?	yes	71.44
If filter is of the standard rate type, has consideration been given in the design to the possibility of the filter being used later for high rate filtration?	desirable	71.44

TABLE 1 (Continued)
TRICKLING FILTER DESIGN - 10 STATES STANDARDS

	Standard	Reference
Standard Rate Filters		
If filter is classified as a standard rate type, are the loadings within these limits?		**
1.1 to 4.4 million gals. per acre per day.	yes	
5 to 25 lbs. BOD ₅ per 1,000 cubic ft. per day.	yes	
The allowable reduction in BOD for a given standard rate filter followed by a settling tank can be obtained from Figure 2 in the Ten States Standards.		71.7
Has the filter been designed to provide the BOD reduction required for a satisfactory effluent?	yes	71.12
Has consideration been given to recirculation?	yes	71.56
High Rate Filters		
If filter is classified as a high rate type, are the loadings within these limits?		
8.7 to 44 million gals. per acre per day.	yes	**
25 to 300 lbs. BOD ₅ per 1,000 cubic feet per day.	yes	**
Is recirculation provided to maintain a continuous dosing rate of at least 8.7 million gallons per acre per day?	yes	**
Does the distribution system provide continuous discharge to the filter, giving no rest period in excess of 15 seconds?	yes	**
Is flow measurement provided for the flow onto the filter or the recirculated effluent if recirculation is used?	yes	**
Are the efficiencies in conformance with the NRC formulas given on pages 166 and 167 in the ASCE Sewage Treatment Plant Design Manual?	yes	**
If the filter is a single-stage high rate, does it fall into one of the types listed on pages 168 and 169 of the Design Manual?	yes	**
Does it meet the requirements listed for each type?	yes	**

*Reference numbers refer to numbers of Sections and Paragraphs of "Ten State Standards" 1968 Edition.

**References taken from the ASCE Sewage Treatment Plant Design Manual.

TABLE 2
CLASSIFICATION OF TRICKLING FILTERS

	Low Rate or "Standard" TF	High Rate TF
Hydraulic Loading		
million gallons/acre/day	1.1-4.4	8.7-44.0
gallons per day/square ft.	25-100	200-1000
Organic Loading		
lbs. BOD ₅ /acre-ft./day	220-1,100	1,100-13,000
lbs. BOD ₅ /1000 cu. ft./day	5-25	25-300
Recirculation	Never	Usually
Depth	5-10'	3-7'
	ave. 7'	ave. 5'

- 1 First, calculate the organic load to be applied to the filter per day.

$$\text{BOD}_5 \text{ in Raw Waste} = 200 \text{ ppm}$$

$$\text{BOD}_5 \text{ in filter influent} = (200) (1.0 - 0.3) = 140 \text{ ppm}$$

$$\text{Organic Load} = (140 \text{ ppm}) \left(\frac{8.34 \text{ lbs.}}{\text{gallon}} \right)$$

$$(10 \text{ mgd}) \left(\frac{\text{lbs. / million lbs.}}{\text{ppm}} \right)$$

$$= 12,000 \text{ lbs. BOD}_5 \text{ per day}$$

- 2 Determine the design organic loading based upon the quality of the filter effluent after sedimentation required for discharge. From TABLE 2, assume a design organic load for a low rate filter of 15 lbs. BOD₅ per 1000 cubic feet per day. From FIGURE 1, the percent of BOD₅ remaining in the effluent at this loading after passing through the filter and final sedimentation would be

17 percent (83% removal). The BOD₅ concentration remaining in the plant effluent after primary and secondary treatment would be equal to,

$$= (200 \text{ ppm}) (1.0 - 0.3) (1.00 - 0.83)$$

$$= 23.8 \text{ ppm}$$

Let us assume this is acceptable for design purposes.

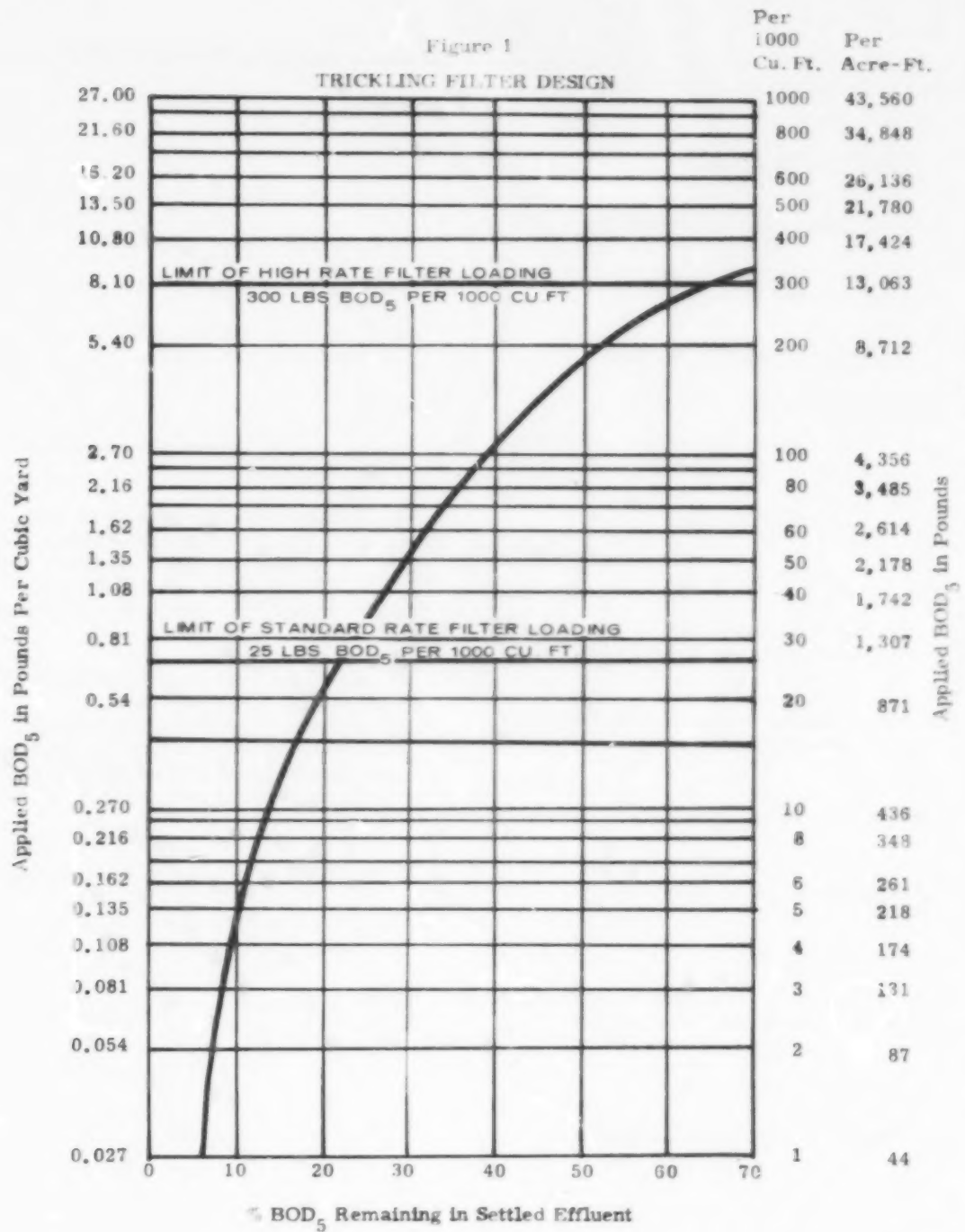
- 3 The required filter volume (V) is then equal to,

$$V =$$

$$\frac{12,000 \text{ lbs. BOD}_5 \text{ per day}}{15 \text{ lbs. BOD}_5 \text{ per day/1000 cu. ft. of filter}}$$

$$V = 800,000 \text{ cubic feet of filter media required}$$

Figure 1



- 4 Assume the filters will be 7 feet deep, then the required total filter area is equal to,

$$A = \frac{\text{Volume}}{\text{Depth}} = \frac{800,000 \text{ feet}^3}{7 \text{ ft.}}$$

$$= 114,300 \text{ square ft.}$$

- 5 Provide six filters, then the required area per filter is equal to,

$$A = \frac{114,300 \text{ ft.}^2}{6 \text{ filters}} = 19,050 \text{ sq. ft. per filter}$$

- 6 Filter bed diameter (Diameter)

$$\text{Filter area} = 19,050 \text{ ft}^2 = \frac{\pi D^2}{4}$$

$$\text{Diameter} = \left[\frac{(4)(19,050)}{(3.1416)} \right]^{0.5}$$

$$= 156 \text{ feet}$$

NOTE: The maximum practical filter bed diameter for construction is limited to 200 feet.

- 7 Checking the hydraulic loading rate to see if it is below the maximum permissible design limit.

Hydraulic Loading =

$$\left(\frac{10 \text{ mgd}}{114,300 \text{ sq. ft.}} \right) \left(\frac{43,560 \text{ sq. ft.}}{\text{acre}} \right)$$

$$= 3.82 \text{ mgd}$$

From TABLE 2, the maximum hydraulic loading rate for a low rate filter is 4.4 million gallons per acre per day.

$$(1.1 < 3.82 < 4.4)$$

Therefore this design is acceptable.

B Design of High Rate Trickling Filters

Example 2

Given:

Sev age Flow Rate (Q) = 10 mgd

BOD₅ in Raw Waste = 200 ppm

BOD₅ in Filter Influent = 140 ppm

BOD₅ in Filter Effluent after sedimentation = 23.8 ppm

Problem:

Design a filter system and check for acceptability.

- 1 From FIGURE 1, the percent of BOD₅ remaining in the plant effluent after passing through the filter and final sedimentation at the organic loading of 100 lbs. BOD₅ per 1000 cubic feet is 40% (60% removal).

In order to produce an effluent of the same quality (23.8 ppm BOD₅ concentration) as provided by the low rate filter designed in Example 1, the maximum organic concentration to be applied to the high rate filter is determined.

$$\text{BOD}_5 \text{ maximum} = \frac{23.8 \text{ ppm}}{0.40} = 59.5 \text{ ppm}$$

As (59.5 < 140), it is necessary to provide recirculation.

- 2 To calculate the required volume of recirculation, balance the organic load applied to the filter using the following expression -

$$\begin{aligned} & (10 \text{ mgd}) \left(\frac{8.34 \text{ lbs.}}{\text{gal.}} \right) (140 \text{ ppm}) \left(\frac{\text{lbs. / million lbs.}}{\text{ppm}} \right) \\ & + (X \text{ mgd}) \left(\frac{8.34 \text{ lbs.}}{\text{gal.}} \right) (23.8 \text{ ppm}) \left(\frac{\text{lbs. / million lbs.}}{\text{ppm}} \right) = \\ & (10 \text{ mgd} + X \text{ mgd}) \left(\frac{8.34 \text{ lbs.}}{\text{gal.}} \right) (59.5 \text{ ppm}) \left(\frac{\text{lbs. / million lbs.}}{\text{ppm}} \right) \end{aligned}$$

Solving for X, which is the volume of recirculation required,

$$(10) (8.34) (140) + (X) (8.34) (23.8) = (10 + X) (8.34) (59.5)$$

$$(1400) + (23.8) (X) = (595) + (59.5) (X)$$

$$(59.5 - 23.8) (X) = (1400 - 595)$$

$$35.7 (X) = 805$$

$$X = 805/35.7 = 22.6$$

Volume of Recirculation = 22.6 mgd

- 3 Calculate the actual organic load to be applied to the filter. It is not equal to 12,000 lbs. BOD₅/day but,

$$\begin{aligned} \text{Organic Load} &= (59.5 \text{ ppm}) \left(\frac{8.34 \text{ lbs.}}{\text{gal.}} \right) \left(\frac{\text{lbs. / million lbs.}}{\text{ppm}} \right) (10 \text{ mgd} + 22.6 \text{ mgd}) \\ &= (59.5) (8.34) (32.6) = 16,180 \text{ lbs. BOD}_5/\text{day} \end{aligned}$$

- 4 Calculate the required filter volume

$$V = \frac{16,180 \text{ lbs. BOD}_5/\text{day}}{100 \text{ lbs. BOD}_5/1000 \text{ cu. ft./day}}$$

$$V = 161,800 \text{ cubic feet of filter media}$$

- 5 From TABLE 2, assume a filter depth of 5 feet,

Required filter area (A) is then equal to

$$A = \frac{\text{Volume}}{\text{Depth}} = \frac{161,800 \text{ cu. ft.}}{5 \text{ feet}} = 32,360 \text{ sq. ft.}$$

6 Filter Diameter (Diam.)

Required Filter Area = 32,360 sq. ft.

Provide (4) filters, then the required area per filter is equal to

$$\frac{32,360 \text{ sq. ft.}}{4 \text{ filters}} = 8,090 \text{ sq. ft. per filter}$$

$$\text{Filter area} = \frac{\pi D^2}{4}$$

$$8,090 \text{ sq. ft.} = \frac{\pi D^2}{4}$$

$$\text{Diam.} = \left[\frac{(4)(8,090)}{\pi} \right]^{0.5} = (10,300)^{0.5}$$

$$\text{Diam.} = 101.5 \text{ feet}$$

- 7 From TABLE 2, the maximum hydraulic loading for a high - rate filter is 44 million gallons per acre per day.

Checking the hydraulic loading rate to see if it falls below this maximum design limit,

$$\text{Hydraulic Loading} = \left(\frac{10 \text{ mgd} + 22.6 \text{ mgd}}{32,360 \text{ sq. ft.}} \right)$$

$$\text{Rate (mgad)}$$

$$\left(\frac{43,560 \text{ sq. ft.}}{\text{acre}} \right)$$

$$= \left(\frac{32.6}{32,360} \right) \left(\frac{43,560}{1} \right)$$

$$= 44 \text{ mgad}$$

$$(44 \approx 44)$$

Therefore this design is acceptable.

IV NATIONAL RESEARCH COUNCIL FORMULA

The National Research Council (NRC) formula for calculation of trickling filter efficiency was developed from military wastewater treatment plant operational data collected during World War II. These formulas are based upon the overall 5-day Biochemical Oxygen Demand

(BOD₅) removal achieved through trickling filtration plus subsequent final settling.

A Single Stage Trickling Filter Design

- 1 The basic NRC formula for the design of single-stage trickling filters is:

$$E = \frac{1}{\left[1 + C \left(\frac{W}{VF} \right) \right]^{0.5}}$$

where,

E = the fraction of BOD₅ removed in the first stage filter

W = the organic load influent to the filter in pounds per day (lbs/day of BOD₅)

$$W = (8.34) Q L_1$$

V = the filter volume in 1,000 cu. ft.

F = the recirculation factor

$$F = \frac{1 + R}{[1 + (1 - p) R]^2}$$

P = fraction of BOD₅ available (0.85 < P < 0.95),

generally use P = 0.90

$$C = 0.0561$$

Q = the flow rate in mgd

L₁ = the influent BOD₅ concentration in mg/l or ppm

R = the recirculation ratio, or the ratio of recirculation flow to the total plant influent flow

- 2 Rearranging terms to solve for the volume of rock media required in the first stage filter, the NRC formula becomes:

$$V = (0.0263) Q L_1 \frac{[1 + (0.1)(R)]^2}{1 + R} \left(\frac{E}{1 - E} \right)^2$$

3 Example 3 - Single Stage Trickling Filter Design

Given: Sewage Flow Rate = 10 MGD

BOD₅ of effluent = 24 ppm

BOD₅ of influent = 140 ppm

$$R = 1.0$$

Find: Required filter volume (V)

- a The fraction of BOD₅ to be removed by the filter (E) is equal to

$$E = \left(\frac{140 - 24}{140} \right) = 0.83$$

- b Solving for the required filter volume (V) using the basic NRC formula,

$$V = (0.0263) Q L_1 \frac{[1 + (0.1)(R)]^2}{(1 + R)} \left(\frac{E}{1 - E} \right)^2$$

$$V = (0.0263) (10 \text{ MGD}) (140) \frac{(1.1)^2}{2} \left(\frac{0.83}{0.17} \right)^2$$

$$= (0.0263) (10) (140) (0.605) (24.3)$$

$$= 542$$

The required filter volume is therefore equal to 542,000 cubic feet.

B Two Stage Trickling Filter Design

- 1 For second stage filters, a decrease in waste treatability is provided in the NRC formula proportional to the amount of BOD removed in the first stage filter and equal to the term

$$\left[\frac{1}{1 - E_1} \right]^2$$

in which E₁ is the efficiency of the first stage. The efficiency of the second stage (E₂) is equal to

$$E_2 = \frac{1}{1 + 0.0561 \left(\frac{W_2}{VF (1 - E_1)^2} \right)^{0.5}}$$

where,

W₂ = the organic load to be applied to the second stage filter

$$W_2 = W_1 (1 - E_1)$$

W₁ = the organic load applied to the first stage filter

- 2 The NRC formula for second-stage filters with terms rearranged to solve for the required filter volume becomes,

$$V = (0.0263) Q L_1 \frac{[1 + (0.1)(R_2)]^2}{1 + R_2} \left[\frac{E_2}{(1 - E_1)(1 - E_2)} \right]^2$$

where,

R₂ = recirculation ratio for the second-stage filter

E₁ = the efficiency of the first stage filter

E₂ = the efficiency of the second filter

$$E_2 = \left[\frac{1}{1 - E_1} \right]^2$$

3 Example 4 - Two Stage Trickling Filter Design

Given: Sewage Flow Rate = 10 MGD

BOD₅ of effluent (L_e) = 24 ppm

BOD₅ of influent (L₁) = 140 ppm

E₁ = 0.6 or 60% BOD₅ removal

$$R_1 = 1.0$$

$$R_2 = 1.0$$

Find:

Required first-stage filter volume (V_1)

Required second-stage filter volume (V_2)

Total required filter volume (V) = ($V_1 + V_2$)

a The required filter volume of the first-stage filter (V_1) is equal to,

$$\begin{aligned} V_1 &= (0.0263) Q L_1 \frac{[1 + (0.1) R_1]^2 \left(\frac{E_1}{1 - E_1}\right)^2}{(1 + R_1)} \\ &= (0.0263) (10) (140) \frac{[1 + (0.1) (1)]^2 \left(\frac{0.6}{1 - 0.6}\right)^2}{(1 + 1)} \\ &= (0.0263) (10) (140) (0.605) (2.25) \\ &= 50 \end{aligned}$$

V_1 is therefore equal to 50,000 cubic feet.

b The required filter volume of the second-stage filter (V_2) is equal to,

$$\begin{aligned} V_2 &= (0.0263) Q L_1 \frac{[1 + (0.1) (R_2)]^2}{(1 + R_2)} \\ &\quad \left[\frac{E_2}{(1 - E_1) (1 - E_2)} \right]^2 \end{aligned}$$

where

L_1 = the BOD_5 of the influent applied to the second stage filter

R_2 = the recirculation ratio for the second stage filter

Solving first for the value of E_2 ,

$$E_2 = 1 - \left(\frac{1 - E_1}{1 - E_1} \right) = 1 - \left(\frac{1 - 0.9}{1 - 0.6} \right) = 0.75$$

Next, determine the BOD_5 content of the influent applied to the second stage filter.

$$L_1 = (140 \text{ mg/l}) (1 - 0.6) = 56 \text{ mg/l}$$

Then, for $R_2 = 1.0$

$$V_2 = (0.0263) (10) (56) \frac{(1 + 0.1)^2}{1 + 1}$$

$$\begin{aligned} &\left[\frac{0.75}{(1 - 0.6) (1 - 0.75)} \right]^2 \\ &= (0.0263) (10) (56) (0.605) (56.25) \\ &= 497 \end{aligned}$$

V_2 is therefore equal to 497,000 cubic feet.

c The total filter volume (V) is equal to,

$$\begin{aligned} V &= (V_1 + V_2) \\ &= (50,000 + 497,000) \\ &= 547,000 \text{ cubic feet} \end{aligned}$$

V ECKENFELDER FORMULA

The basic Eckenfelder Formula for treatment of sewage and industrial wastes by BOD_5 removal is:

$$\frac{L_e}{L_o} = \frac{1}{1 + \frac{CD^{0.67}}{(QA)^{0.5}}}$$

where

L_e = the BOD_5 concentration remaining in the filter effluent, in mg/l

L_o = the BOD_5 concentration actually applied to the filter, including influent flow plus recirculation

Q = sewage flow rate in mgd

A = filter area in acres

D = depth of filter in feet

C = 2.5

Eckenfelder defined the influence of recirculation on waste treatment with the following expression:

$$L_o = \frac{L_i + R L_e}{1 + R} \quad \text{in which,}$$

L_o = the mg/l of BOD_5 actually applied to the filter

L_e = the mg/l of BOD_5 in the filter effluent

L_i = the mg/l of BOD_5 contained in the settled raw sewage waste

R = the recirculation ratio

A Single-Stage Trickling Filter Design

- 1 Rearranging terms to solve for the volume of rock required, the Eckenfelder formula for the design of single stage trickling filters becomes:

$$V = (7.0) \frac{Q}{D^{0.33}} \left[\frac{E}{(1 - E)(1 + R)} \right]^2$$

where,

V = filter volume in 1000 cubic feet

Q = sewage flow rate in mgd

D = filter depth in feet

E = the fraction of BOD_5 removed, or the efficiency of the filter stage

R = the recirculation ratio

2 Example 5 - Single Stage Trickling Filter Design using the Eckenfelder Formula

Given: Sewage Flow Rate = 10 MGD

BOD_5 of effluent (L_e) = 24 ppm

BOD_5 of influent (L_i) = 140 ppm

$R = 1.0$

$T = 20^\circ C$

$D = 7.0$ feet

Find: Required filter volume (V)

a Filter efficiency (E) is equal to,

$$E = \left(\frac{L_i - L_e}{L_i} \right) = \left(\frac{140 - 24}{140} \right) = 0.83$$

b The required filter volume (V) is equal to,

$$V = 7 \frac{Q}{D^{0.33}} \left[\frac{E}{(1 - E)(1 + R)} \right]^2$$

For $R = 1$ and $D = 7$ ft.,

$$V = \frac{(7)(10)}{(7)^{0.33}} \left[\frac{(0.83)}{(1 - 0.83)(1 + 1)} \right]^2$$

$$= \frac{(7)(10)(0.689)}{(1.915)(0.1157)}$$

$$V = \left(\frac{48.2}{0.22} \right) = 218, \text{ or } 218,000 \text{ cubic feet}$$

B Two-Stage Trickling Filter Design

- 1 The Eckenfelder Formula for the design of two-stage trickling filters becomes,

$$V = \frac{7 Q}{D^{0.33}} \left[\frac{E_2}{(1 - E_1)(1 - E_2)(1 + R)} \right]^2$$

$$\text{where } E_2 = \left[1 - \frac{(1 - E)}{(1 - E_1)} \right]$$

2 Example 6 - Design of Two-Stage Trickling Filter using the Eckenfelder Formula

Given: Sewage Flow Rate (Q) = 10 MGD

BOD₅ of effluent (Le) = 24 ppm

BOD₅ of influent (Li) = 140 ppm

E₁ = 0.6 or 60%

R₁ = 1.0

R₂ = 1.0

D = 7.0 ft.

T = 20°C

Find:

Required First-Stage Filter Volume (V₁)

Required Second-Stage Filter Volume (V₂)

Total required filter volume (V) = (V₁ + V₂)

a First-Stage Filter Volume (V₁)

$$V_1 = \frac{7 Q}{D^{0.33}} \left[\frac{E_1}{(1 - E_1)(1 + R)} \right]^2$$

$$= \frac{(7)(10)}{(7)^{0.33}} \left[\frac{(0.6)}{(1 - 0.6)(1 + 1)} \right]^2$$

$$= \frac{(7)(10)(0.36)}{(1.915)(0.64)} = 20.6$$

The required first-stage filter volume (V₁) is therefore equal to 20,600 cubic feet.

b Second-Stage Filter Volume (V₂)

$$E_2 = \left[1 - \frac{(1 - E_1)}{(1 - E_1)} \right] = \left[1 - \frac{(1 - 0.83)}{(1 - 0.6)} \right]$$

$$= \left[1 - \frac{(0.17)}{(0.4)} \right] = (1 - 0.425)$$

$$E_2 = 0.575$$

$$V_2 = \frac{7 Q}{D^{0.33}} \left[\frac{E_2}{(1 - E_1)(1 - E_2)(1 + R_2)} \right]^2$$

$$= \frac{(7)(10)}{(7)^{0.33}} \left[\frac{(0.575)}{(1 - 0.6)(1 - 0.575)(1 + 1)} \right]^2$$

$$= \frac{(7)(10)(0.33)}{(1.915)(0.1155)} = 104.8$$

The required second-stage filter volume is therefore equal to 104,800 cubic feet.

c The total required filter volume (V) is equal to,

$$V = (V_1 + V_2)$$

$$= (20,600 + 104,800)$$

$$= 125,400 \text{ cubic feet}$$

VI GALLER - GOTAAS FORMULA

Design charts derived from the Galler-Gotaas formulations for biological waste treatment-design are provided in this section of the outline. These charts are based upon the following formula which was developed from a multiple regression analysis of operational data from existing sewage treatment plants:

$$L_e = \frac{(0.464) (L_o)^{1.19} (1 + R)^{0.28} (Q/A)^{0.13}}{(1 + D)^{0.67} (T)^{0.15}}$$

where,

L_o = the concentration of BOD_5 in the combined influent (recirculation plus raw settled sewage) to be applied to the filter.

L_e = the concentration of BOD_5 of the effluent from the filter in mg/l.

R = the recirculation ratio or the ratio of recirculation flow to plant influent flow.

Q = the sewage flow rate in million gallons per day (mgd).

A = filter area, in square feet.

D = depth of filter in feet.

T = the temperature of the wastewater in degrees centigrade.

A Single Stage Trickling Filter Design

- 1 Rearranging terms to solve for the volume of rock required, the Galler-Gotaas formula for the design of single stage trickling filters becomes--

$$V = (0.1355) (D) \frac{(Q)^{0.13} (L_i)^{0.19} [1 + R (1 - E)]^{1.19}}{(T)^{0.15} (1 + D)^{0.67} (1 - E) (1 + R)^{0.78}}$$

- 2 Figures 2, 3, 4 and 5 have been developed from the above equation. These graphs may be used to design a single-stage or first-stage trickling filter.

Figure 2 is for the design of a single-stage trickling filter with an influent flow rate of 1.0 mgd, an influent BOD_5 waste concentration of 100 mg/l, filter depth of 6.0 feet, and a wastewater temperature of 20°C. Figures 3, 4 and

5 give factors to correct the required filter volume for other values of filter depth, influent waste concentrations and flow rates, respectively. The design procedures to be followed are illustrated in Example 7 which follows:

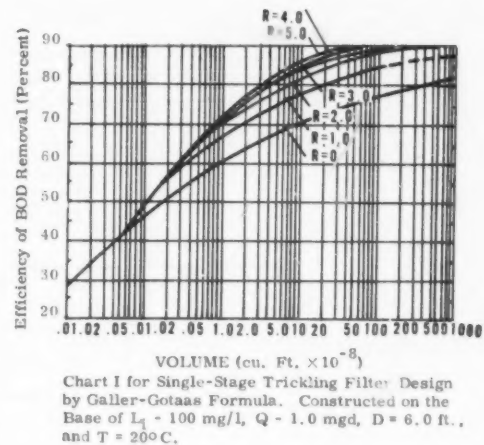


Figure 2

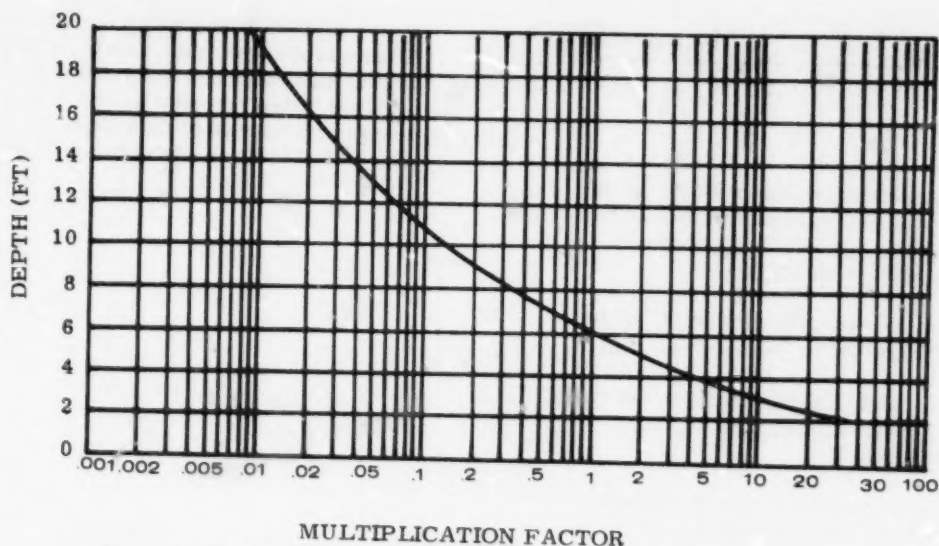


Chart II for Single-Stage Trickling Filter Design by Galler-Gotaas Formula. Multiply Volume Determined from Chart I by Appropriate Factor from Chart II for Filter Depths other than 6 ft.

Figure 3

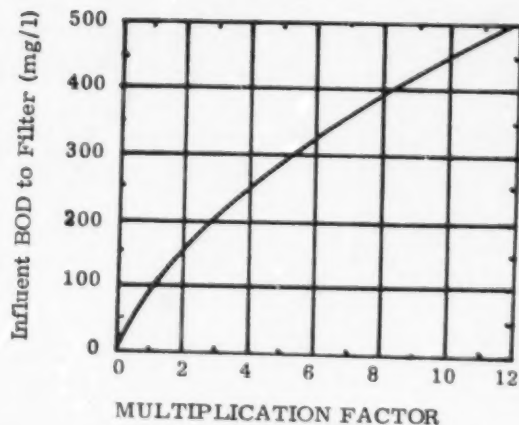


Chart III for Single-Stage Trickling Filter Design by Galler-Gotaas Formula. Multiply Volume Determined from Chart I by Appropriate Factor from Chart III for Influent BOD concentrations other than 100 mg/l

Figure 4

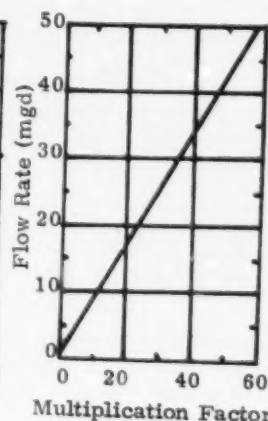


Chart IV for Single-Stage Trickling Filter Design by Galler-Gotaas Formula. Multiply Volume determined from Chart I by appropriate factor from Chart IV for Plant Flow Rates Other than 1.0 mgd.

Figure 5

3 Example 7 - Single-Stage Trickling Filter Design using the Modified Galler-Gotaas Formula

Given: Sewage Flow Rate = 10 MGD

BOD₅ of effluent (Le) = 24 ppm

BOD₅ of influent (Li) = 140 ppm

R = 1.0

Find: Required filter volume (V)

- a The fraction of BOD₅ to be removed by the filter (E), or the required efficiency of the filter is equal to,

$$E = \frac{Li - Le}{Li} = \frac{140 - 24}{140} = 0.83 \text{ or } 83\%$$

- b Assume that the wastewater temperature is 20°C. If it is not, the required filter volume must be corrected by the factor

$$\frac{20}{T}^{0.15}$$

- c From Figure 2, with a recirculation ratio (R) equal to 1.0, the required filter volume (V) is equal to 60,000 cubic feet. Assume a filter depth (D) of 7 feet. From Figure 3, the multiplication factor to correct the filter volume for this depth is equal to 0.6.

From Figure 4, the multiplication factor to correct the filter volume for the influent BOD₅ concentration of 140 ppm is equal to 1.6.

From Figure 5, the multiplication factor to correct the filter volume for the sewage flow rate of 10 MGD is equal to 11.0. The corrected filter volume required (V) is then equal to,

$$V = (60,000) (0.6) (1.6) (11) \\ = 633,000 \text{ cubic feet}$$

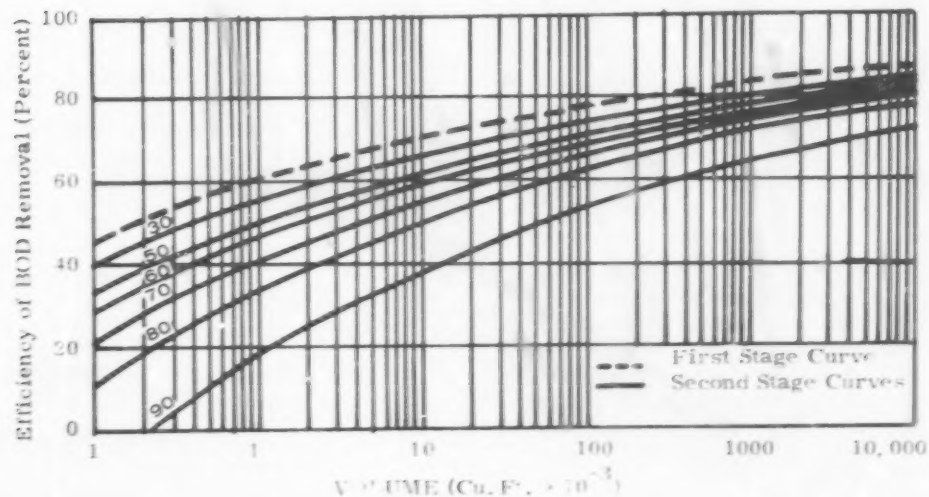


Chart I for Two-Stage Trickling Filter Design by the Galler-Gotaas Formula. Constructed on the Base of $L_i = 100 \text{ mg/l}$, $Q = 1.0 \text{ mgd}$, $R = 0.0$, $D = 6.0 \text{ ft.}$, and $T = 20^\circ \text{C}$.

Figure 6

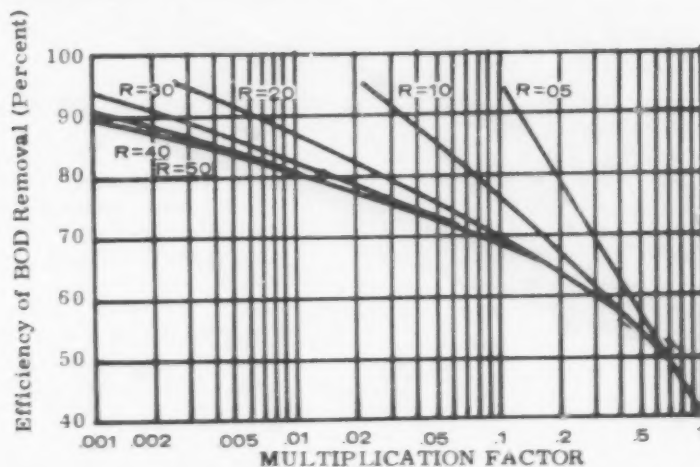


Chart II for Two-Stage Trickling Filter Design by Galler-Gotaas Formula. Multiply Volume from Chart I by Appropriate Factor for Filters with Recirculation.

Figure 7

B Two-Stage Trickling Filter Design

- 1 Rearranging terms to solve for the volume of filter rock required and introducing the term $[1/(1 - E_1)]^4$ to correct for reduced waste treatability, results in the following equation for design of two-stage trickling filter systems:

$$V = (0.1355) (D)$$

$$\left[\frac{(Q)^{0.13} (L_i)^{0.19} (1 + R) (1 - E_2)^{1.19}}{(T)^{0.15} (1 + D)^{0.67} (1 - E_2) (1 + R)^{0.78} (1 - E_1)^{0.5}} \right]$$

- 2 Figures 6 and 7 have been developed from the above equation. These graphs may be used to design a two-stage trickling filter. Figures 3, 4 and 5 give factors to correct the required filter volume for other values of filter depth, influent waste concentrations and flow rates, respectively.

The design procedures to be followed are illustrated in Example 8 which follows:

- 2 Example 8 - Two Stage Trickling Filter Design using the Modified Galler - Gotaas Formula

Given: Sewage Flow Rate = 10 MGD

BOD₅ of effluent (Le) = 24 ppm

BOD₅ of influent (Li) = 140 ppm

E₁ = 0.6 or 60%

R₁ = 1.0

R₂ = 1.0

T = 20°C

Find: Required First-Stage filter volume (V₁)

Required Second-Stage filter volume (V₂)

Total required filter volume (V) = (V₁ + V₂)

- a From Figure 6, with a first-stage filter BOD₅ removal efficiency equal to 60%, the required filter volume is 1,200 cubic feet.

From Figure 7, with a recirculation ratio (R_1) equal to 1.0, the multiplication factor to correct the filter volume for a recirculation ratio of this value is equal to 3.3. Assume a first-stage filter depth equal to 7.0 feet. From Figure 3, the multiplication factor to correct the filter volume for this depth is equal to 0.6.

From Figure 4, the multiplication factor to correct the filter volume for the influent BOD₅ concentration of 140 ppm is equal to 1.6.

From Figure 5, the multiplication factor to correct the filter volume for the sewage flow rate of 10 MGD is equal to 11.0. The corrected first-stage filter volume (V_1) is then equal to,

$$V_1 = (1,200) (3.3) (0.6) (1.6) (11.0) \\ = 41,800 \text{ cubic feet}$$

- b The required second-stage BOD₅ removal efficiency (E_2) is equal to,

$$E_2 = \left[1 - \frac{(1 - E_1)}{(1 - E_1)} \right] \\ = \left[1 - \frac{(1 - 0.83)}{(1 - 0.6)} \right] = \left[1 - \frac{0.17}{0.40} \right] \\ = (1 - 0.425) \\ = 0.575$$

- c From Figure 6, the required second-stage filter volume is equal to 5,000 cubic feet.

From Figure 7, with a recirculation ratio (R_2) equal to 1.0, the multiplication factor to correct the filter volume for a recirculation ratio of

this value is equal to 4.1. Assume a second-stage filter depth equal to 7.0 feet. From Figure 3, the multiplication factor to correct the filter volume for this depth is equal to 0.6.

From Figure 4, the multiplication factor to correct the filter volume for the influent BOD₅ concentration of 56 ppm or $[140 \text{ ppm} \times (1 - 0.6)]$ is equal to 0.5.

From Figure 5, the multiplication factor to correct the filter volume for the sewage flow rate of 10 MGD is equal to 11.0. The corrected second-stage filter volume (V_2) is then equal to,

$$V_2 = (5,000) (4.1) (0.6) (0.5) (11.0) \\ = 67,600 \text{ cubic feet}$$

- d The total required filter volume (V) is then equal to,

$$V = (V_1 + V_2) \\ = (41,800 + 67,600) \\ = 109,400 \text{ cubic feet}$$

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EXPERIENCE IN THE USE OF RAW SEWAGE LAGOONS

I INTRODUCTION

- A Lagoons receiving raw sewage have become very popular, particularly among smaller municipalities where low construction and operating costs usually offer a significant financial advantage over other conventional treatment methods. Lagoon installations in the Missouri Basin serving as the sole mode of treatment now number several thousand.

II HISTORY OF DEVELOPMENT

- A As early as 1920, a few cities in California, Texas, North Dakota, and probably other states were using lagoons as a means of treating municipal sewage. However, in each case it seemed to be more the result of accident than actual design.
- 1 About this time, a student of the University of Texas made a study for the State Department of Health to ascertain why sewage from the town of Palestine, which was discharged into a small swampy area, was converted to a fresh sparkling stream after a few miles. The report that aquatic plants played an important part in the oxidation of this sewage was subjected to ridicule. However, a short time later, the State Sanitary Engineer recommended that Abilene, Texas construct a small dam and pond their sewage until a sewage treatment plant could be built. This early lagoon functioned successfully, and during the 1930's Texas A & M College became interested in the operations at Abilene and constructed a 14-acre unit to carry on limited investigations of lagoon operation. What happened to this study is not known.
 - 2 In 1924 Santa Rosa, California in an attempt to provide low-cost sewage disposal, uncovered gravel beds which the City Council thought could be used

as natural filters before the city sewage was discharged into Santa Rosa Creek. The exposed gravel soon became sealed from sewage solids, resulting in a sewage pond about 3 feet deep. The effluent from the pond resembled the effluent from a trickling filter. It had no odor and was easily disinfected. Also, in 1924, Vacaville, California constructed a small reservoir in a dry gully to impound sewage during the winter months only. Here again, it was found that this impounded sewage underwent characteristic reduction in BOD and increased in dissolved oxygen.

- 3 In 1928, Fessenden, North Dakota, completed a sewer system but did not have funds to complete a treatment plant. As an emergency measure, the sewage was drained into a pothole about a mile from town. Forty years later, this natural lagoon is still in operation.

- 4 The success of these early enterprises eventually gave engineers and health authorities some degree of confidence that a raw sewage lagoon could be designed and operated satisfactorily in close proximity to a City.

B Modern Raw Sewage Lagoons

- 1 The first lagoon built on sound engineering principles under modern concepts of treating raw sewage, was the one placed in operation in 1948 at Maddock, North Dakota. To my knowledge, this was the first lagoon built to receive raw sewage under plans formally approved by an official Health Agency. "Engineered lagoons" had been built in both Texas and California before this time, but to receive effluent from primary treatment plants rather than raw sewage. For the most part, the early facilities in Texas and California were apparently

constructed to store partially treated sewage effluents for subsequent release for irrigation.

- 2 Maddock is a town of approximately 1,000 people. The initial design provided 10 acres of water service in a single cell, a level bottom, a water depth of 5 feet, and uniform bank slopes. Observations of this facility and laboratory analysis confirmed that a high degree of BOD reduction prevailed at any point 50 feet or more from the inlet at the center of the pond.
- 3 The success of this installation created considerable enthusiasm by engineers of the North Dakota State Health Department, and they soon became active promoters of lagoons as an accepted method of sewage treatment. Several towns in North Dakota constructed lagoons in 1949. It should be mentioned that these facilities, and the engineers recommending them, were harshly criticized for what was then considered a backward step in sewage treatment. With very few exceptions, consulting engineers in particular were reluctant to accept lagoons as sewage treatment plants.
- 4 A few City Councils recognized lagoons as the most economic solution to their money and water pollution problems, and insisted that lagoons rather than conventional plants be designed and constructed. In some instances, communities previously unable to finance both a sewer system and conventional sewage treatment works, were able and did construct sewer systems and lagoons.
- 5 Endorsement by the U.S. Public Health Service of lagoons as an acceptable method of sewage treatment was first given by the Missouri Drainage Basin Office, serving a 10-state area in Midwestern United States. As engineer in charge of the Water Pollution Control Program of the Public Health Service in the Missouri Basin, my own

observations, supported by the investigative work by Dr. Joe K. Neel, biologist on my staff, permitted us to officially endorse this method of sewage treatment.

- 6 Enthusiasm also spread to the Taft Sanitary Engineering Center of the Public Health Service in Cincinnati, Ohio, as W.W. Towne, then in charge of Field Investigations at the Center, became actively interested in investigations of facilities then existing in North and South Dakota. In 1954 the Public Health Service started limited field investigations of 3 lagoons in each of the 3 states. The report brought about a degree of respectability that raw sewage lagoons had not previously enjoyed. Today, lagoons are being used in virtually every State in the Union, but nowhere do they predominate in sewage works construction as they do in the Missouri Basin.

C Missouri Basin Standards

- 1 One by one and with varying degrees of enthusiasm, the State Sanitary Engineers of the 10 Missouri Basin States began to accept raw sewage lagoons. Each state promulgated its own design standards and criteria, although each was generally patterned after the original installations in North Dakota. The great upsurge of interest in the use of lagoons at many localities throughout the Basin soon emphasized the desirability of documenting the design, construction and operation practices generally used. At its 1958 meeting at Deadwood, South Dakota, the Missouri Basin Engineering Health Council, consisting of the Chief Sanitary Engineer of each of the 10 Basin States, recognized this need and appointed a committee to accomplish the objective. It was my good fortune to be one of the three men appointed to the Committee, and my further good fortune that I was requested to develop a preliminary draft of a report for review by the other two members of the Committee.

- 2 Upon acceptance by the three-man committee, the draft was submitted to each of the 10-state Sanitary Engineers for review and comment. A succession of drafts and redrafts followed, and eventually one was acceptable to each of the 10 states. This draft was approved by the Missouri Basin Engineering Health Council at its meeting in Jefferson City, Missouri on January 21, 1960. The Committee report was carried in the September 1960 issue of the Journal Water Pollution Control Federation. Today it still constitutes the most reliable treatise on design, construction and operation practices of raw sewage.

D Treatment Process

Primary and secondary treatment processes are usually accomplished in separate units. A lagoon accomplishes both gravity separation and biological reduction in a single unit.

- 1 Sludge settles to the bottom. Except in the vicinity of the inlet, it is rather uniformly distributed over the entire lagoon bottom. Circulation resulting from surface winds and convection currents contribute to the scatter.
- 2 Sludge decomposition progresses somewhat comparable to an unheated digester. The liquid immediately above the sludge layer is anaerobic, but the upper portion of the water reservoir is normally aerobic. As hydrogen sulphide is released, it passes upward through the aerobic zone and reacts with water before reaching the open atmosphere. Objectionable odors may develop only when the entire water strata is anaerobic. Freedom from odor is assured only when oxygen is present in the upper layers. Oxygen production must thus exceed the demands of organic decomposition.
- 3 Light intensity seems to be the most important influence upon the rate of photosynthesis. The rate declines with the autumn and winter declines in light intensity, with a corresponding resurgence in the spring and following periods of overcast.
- a Observations by the Public Health Service at Fayette, Missouri have shown that there should be at least 1 1/2 langley of solar radiation² (1 langley = 1 gram calorie per CM²) per day for each pound of BOD applied per acre of lagoon surface/day. To insure a safety factor 1 lb of BOD per acre for 2 langleys is suggested. Loading in lbs BOD per acre per day should thus be equal to one half the minimum daily langley level for the month with least solar radiation. This relation does not hold if ice cover endures over the winter months.
- 4 The Lagoon provides an environment favorable for the interactions of algae and bacteria. Bacteria feed upon constituents of sewage in solid form and in solution and render them innocuous. Algae utilize carbon dioxide and other substances resulting from bacterial action and, through photosynthesis, produce oxygen needed for anaerobic bacterial action. During the detention period, the objectionable characteristics of sewage largely disappear.
- 5 Lagoons normally employ a detention period of 60 to 90 days, although detention over 120 days is not uncommon. A detention as short as 30 days insures a high degree of coliform removal.
 - a Series installations increase BOD removals. Effluent from secondary units of a series operation has lower concentrations of algae, color, turbidity.
 - b Design of installations in series must recognize that the entire sludge load will adhere to the primary cell.

E. Advantages of Lagoons

- 1 Construction cost is usually much lower than for other treatment processes. For smaller communities, where suitable land is often readily available at reasonable cost, the cost of sewage treatment may be reduced by more than 50 per cent.
 - a Many smaller communities previously unable to finance a sewage system and treatment works have been able to finance their sewer system and a lagoon for treatment.
 - b In certain states, lagoons have saved communities more than they have gained through Federal Aid.
- 2 The cost of maintenance is much lower. Highly skilled operators are not required. Maintenance is usually limited to weed control and dike maintenance. Break-downs are virtually non-existent.
- 3 A lagoon has tremendous ability to handle shock loads. The "slug" is immediately diluted, and tremendous "slug loads" are required to upset the lagoon process.
 - a Lagoons are well suited for summer camps, rural schools, motels, resorts, slaughter houses, livestock operations, etc. Missouri is estimated to have more than 1,000 non-municipal lagoons.
 - b Design may provide for complete retention, or may provide for controlled release at a non-critical time.
- 4 Lagoons may serve well as interim facilities in developing areas. When development is adequate to support trunk or interceptor sewers, the lagoon can be abandoned at little loss of investment. Increase in land values may even offset all construction costs. This has been widely practiced in Kansas City, where approximately 40 developer financed lagoons have served as interim facilities.
 - a Under its revenue bond program, Kansas City has constructed 2 lagoon systems to serve the intermediate portions of large watersheds, pending the development of sufficient customer load to warrant construction of 8 to 12 miles of large diameter sewers.
- 5 Lagoons may be used for treating industrial wastes that are amenable to biological treatment, or a mixture of organic industrial wastes and domestic sewage. Installations are now successfully serving oil refineries, slaughter houses, dairy and creamery establishments, poultry processing plants, and rendering plants. Special study should be given industrial wastes whenever they constitute a significant portion of the total load. Possible toxic effects of industrial wastes should not be overlooked. Toxic materials in concentration that would interfere with other biological sewage treatment processes should be handled in lagoons only after thorough study and evaluation.
- 6 Lagoons may receive raw sewage, or the effluent of a conventional treatment plant.
 - a Numerous instances can be cited where lagoons provide "polish treatment," following a trickling filter or activated sludge plant. They are particularly effective in coliform reduction.
 - b Where provided initially to receive raw sewage from sparsely developed areas, lagoon designed to receive raw sewage may later be used to provide secondary treatment, as primary treatment facilities are provided to relieve the overload from increased development.
- 1) This has been used very successfully at Kansas City in the intermediate reaches of the Little Blue River Basin, and comparable use is planned in our Shoal Creek Watershed.

7 Lagoons surpass other conventional treatment processes in reduction of total phosphorus and total nitrogen.

- a Investigations at Fayette, Missouri demonstrate consistent reductions of total phosphorus by 85 per cent; and total nitrogen by 92 per cent.

F Disadvantages of Lagoons

- 1 Too little is known regarding the many factors which affect optimum performance of lagoons. Unfortunately, lagoons have remained beneath the dignity of established research talent. As a result, research in this field has been fragmentary.
- 2 Too frequently, lagoons are permitted to operate with no supervision or control. Overloading is not prevented, and the problem is not apparent until some critical circumstance occurs -- as a long period of cloudy weather or an abrupt change from cold to warm weather. Little can be done to prevent reoccurrence of the problem.
- 3 With a breakdown in the process, lagoons become quite odorous. With the large area of water surface, a severe nuisance can occur over a wide area.
- 4 A lagoon requires a much greater land area than do other treatment processes. Add to this basic area the distance that should be provided to reasonably isolate a sewage plant, and a very large area results. This may be feasible for an interim period but not as a permanent installation.
- 5 Poor maintenance may lead to emergent vegetation, which in turn can lead to mosquito propagation. The major species produced in lagoons are culex tarsalis and culex pipiens -- both primary vectors of encephalitis. Mosquitoes do not propagate in a properly maintained lagoon.

G Summary

- 1 Sewage lagoons are a proven and demonstrated method of satisfactory waste disposal to be considered along with other accepted methods of treatment, in the engineering and economic analysis that leads to the final selection of a sewage treatment process. This does not imply that the lagoon is the answer to all sewage problems. However, a lagoon provides the most feasible method of sewage treatment in many instances.
- 2 Reference material
 - a The most informative document on the design, construction and operation of lagoons is the Committee Report of the Missouri Basin Engineering Health Council. I have with me several copies of this publication for any one interested.
 - b Proceedings of Symposium on Waste Stabilization Lagoons. This Symposium was conducted at Kansas City, Missouri, August 1-5, 1960 by Region VI, Public Health Service, at the request of the 10 states of the Missouri Basin. I believe the Kansas City office of FWPCA still has a limited supply of this publication, and that it can be made available upon request.

This outline was prepared by G. J. Hopkins, Director, Water and Pollution Control Depts., City of Kansas City, MO 64106.

STATUS OF ADVANCED WASTE TREATMENT

I The Federal Water Quality Administration is conducting an accelerated national program on advanced waste treatment research. Program objectives are to improve existing waste treatment processes and to develop and demonstrate practical means of removing maximum possible amounts of physical, chemical, and biological pollutants. Emphasis in advanced waste treatment studies is being placed both on treatment as a water pollution control measure and treatment for water reuse.

This discussion will cover the current status of Federal Water Quality Administration research on advanced waste treatment with emphasis on costs and design factors and processes for nutrient removal. Nutrient removal and processes for increased removal of BOD and suspended solids have high research and development program interest at this time.

A Research and development programs are conducted under four mechanisms:

- 1 in-house studies
- 2 Research grants to universities and nonprofit organizations
- 3 Research and development grants to cities, sanitary districts, and states, and
- 4 Research contracts

B Research contracts are awarded principally for determination of technical and economic feasibility of new and novel treatment techniques, and for extension of in-house studies. Most contract work scopes include laboratory studies, pilot-scale studies, and desktop analyses. In some cases, it is necessary to conduct larger scale studies to develop reliable design, operating cost, and maintenance cost data. If feasibility is established, a process is progressively evaluated in large-scale facilities to establish reliable design, performance, and cost data. The later phases of process development are usually conducted in Federal Water Quality Administration pilot plants or by award of cost-sharing Research and Development Grant for pilot plant or full-scale plant studies.

During 1969 there were 93 advanced waste treatment research contracts in force

with a total cost of 8.9 million. An additional 30 contracts were being processed at a cost of 2.2 million.

Forty-eight research and development grants were in force with a total cost of 25.7 million.

II SPECIFIC PROJECTS

A Processes for removal of suspended materials include sedimentation, screening coagulation-sedimentation, and filtration.

- 1 Microscreening equipment for removal of solids from secondary effluent is available employing a rotary drum configuration. A disadvantage of this method is susceptibility to wide variations in flow and suspended solids. Seventy-five percent of suspended solids and sixty percent of BOD can be removed from secondary effluent by this method.
- 2 Filtration with sand or multi-media filters can be utilized. A higher degree of removal can be obtained by coagulation-sedimentation with or without filtration.

B Processes for removal of organic materials include biological, physical and chemical methods. Biodegradable organics may be removed by conventional biological treatment, with or without coagulation or filtration to remove particulates and by activated carbon adsorption. Removal of nonbiodegradable organics can be accomplished by activated carbon adsorption and chemical oxidation.

- 1 Extensive studies have been conducted on activated carbon treatment. Treatment by use of granular and powdered carbon has been evaluated. Granular carbon treatment is accomplished by contacting water with a fixed bed of carbon. Flow rates are normally 4 to 6 gallon per minute per square foot. Bed depth is designed to provide contact times of 20 to 40 minutes.
- 2 The use of powdered activated carbon for wastewater treatment is accomplished by slurry contacting. After contacting, the powdered carbon is settled out along with suspended solids. Filtration of settled effluent will produce a high quality water.

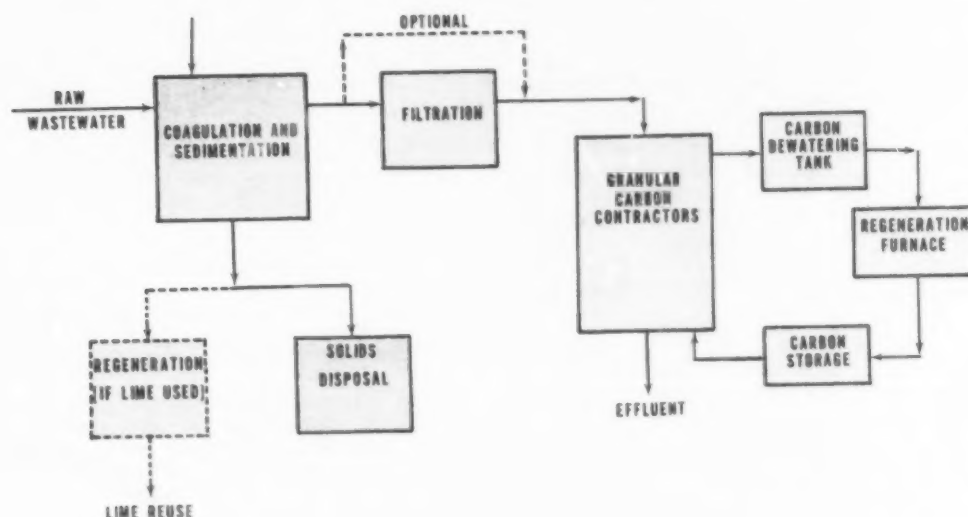


FIGURE 1
PHYSICAL CHEMICAL ALTERNATIVE TO BIOLOGICAL TREATMENT

TABLE I	
ORGANIC REMOVAL	
<u>Biodegradable Organics</u>	
A	Biological Treatment
	Trickling Filter
	Activated Sludge
B	Removal of Particulate BOD by Same Process as shown for Suspended Solids
C	Activated Carbon Adsorption
<u>Non-Biodegradable Organics and Color</u>	
A	Activated Carbon Adsorption
B	Chemical Oxidation
3	In order for use of activated carbon to be economical, regeneration and reuse is necessary. Granular carbon can be regenerated in a multiple-hearth furnace. Methods for regeneration of powdered carbon are being developed.

C Nitrogen and phosphorus removal occupy major interest because these nutrients tend to be highly soluble, recycle readily, are difficult to remove effectively and are associated with major problems in surface water eutrophication.

TABLE II	
NUTRIENT REMOVAL	
<u>Nitrogen</u>	
A	Biological Nitrification - Denitrification
B	Ammonia Stripping by Air Contacting
<u>Phosphorus</u>	
A	Chemical Precipitation with Inorganic Salts
B	Biological Removal
C	Ion Exchange

Nitrogen can be removed by biological nitrification-denitrification and ammonia stripping by air contacting. Phosphorus can be removed by chemical precipitation with inorganic salts, biological processes, and ion exchange.

Processes are being or will be evaluated at many locations. Many pilot-scale and full-scale plants are now in the design and construction stages.

- 1 Nitrogen can be removed by the progressive biological conversion of nitrogen to nitrogen gas. This involves use of both aerobic and anaerobic biological steps. Nitrification is typically achieved in an activated sludge aeration tank by extending the normal aeration time and by employing lower ratios of BOD to mixed liquor suspended solids than usual. Denitrification results from anaerobic bacteria utilizing oxygen from nitrates and nitrites. Since the nitrified effluent is deficient in carbon, this stage of treatment requires the addition of an organic supplement such as methanol. The denitrification step may be achieved in a separate tank with mechanical mixing or by developing a population of denitrifying organisms within carbon columns or sand filters following the aerators.
- 2 Ammonia stripping is incorporated into the 2-stage lime precipitation process. Lime is added to the first stage to raise the pH to 11. Effluent from the first-stage clarifier is contacted with air in a cooling tower for ammonia removal.
- 3 Phosphorus can be removed by addition of inorganic coagulants at several steps in conventional treatment; raw sewage, mineral addition to the aerator in activated sludge, and by tertiary clarification. Costs for various processes will be discussed later.
- 4 Chemical coagulation, sedimentation, filtration, and granular carbon adsorption are being evaluated at seven locations at flows up to 7.5 million gallons per day. Plants are located at South Lake Tahoe, California; Piscataway, Maryland; East Chicago, Indiana; Nassau County, New York; Dallas, Texas; Washington, D.C.; and Lebanon, Ohio. The treatment facility at Lake Tahoe has been in operation at 2.5 mgd for several years

and has been expanded. Other plants not included are Colorado Springs at 2 mgd and Chicago at 1 mgd.

TABLE III

PILOT PLANT AND FULL-SCALE
PLANT STUDIES

CHEMICAL COAGULATION, SEDIMENTATION
FILTRATION, AND GRANULAR CARBON
ADSORPTION

	FLOW MGD
1 S. Lake Tahoe, CA	7.5
2 Piscataway, MD	5
3 E. Chicago, IN	0.75
4 Nassau Co., NY	0.55
5 Dallas, TX	0.15
6 Washington, DC	0.10
7 Lebanon, OH	0.07

- 5 A schematic diagram of the Tahoe treatment system is shown on Figure 2. Lime is added in the first stage to raise the pH to 11. This step removes most of the suspended solids, phosphates, and carbonate compounds. Effluent from the first-stage clarifier is then subjected to counter-current air contacting to remove ammonia; effluent from the cooling tower is recarbonated with CO_2 to precipitate excess calcium as CaCO_3 in the second-stage clarifier; at this point the pH is dropped to 9.5. Addition of small dosages of alum, polyelectrolyte or activated silica ahead of the filters may be necessary to maintain product clarity in the second-stage effluent. The final treatment step is granular carbon adsorption. Carbon and lime are regenerated for reuse at this facility. Facilities are not provided for demineralization.
- 6 Figure 3 is a schematic of the Santee, California plant. Nearly all processes being studied for tertiary treatment are represented here. Biological nitrification-denitrification is used with an organic feed source being added

prior to the denitrification step, followed by chemical coagulation, sedimentation and filtration. Flow is 2 mgd. A side stream of 50,000 gal./day will be subjected to additional treatment to produce a water of similar quality to potable water. Treatment includes carbon adsorption, demineralization, and chlorination. Electrodialysis and ion exchange will be studied in parallel for demineralization.

- 7 Table 4 shows pollutant removal for tertiary processes. Secondary effluent is assumed to have 20 mg/1 suspended solids and 13 BOD. Microscreening or rapid sand filtration will produce an effluent with 6mg/1SS and 8 mg/1 BOD. Lime clarification, filtration and granular carbon adsorption will produce an effluent containing 2 mg/1 of SS and 2 mg/1 of BOD.

TABLE IV

TERTIARY SUSPENDED SOLIDS AND BOD REMOVAL

	Tertiary Effect	
	BOD MG/L	SS MG/L
Rapid Sand Filtration	8	6
Chemical Clarification	6	2
Chemical Clarification and Filtration	5	1
Filtration and Granular Carbon Adsorption	2	2

- 8 As discussed earlier, phosphorus can be removed by chemical treatment of raw sewage, mineral addition to the aerator in the activated sludge process, and tertiary clarification. Careful study of each design problem is required to determine treatment location and choice of chemicals.
- 9 Alternate chemical systems are shown here. Iron coagulants are ferrous chloride, commercial or waste pickle liquor, and ferric chloride. Aluminum is added in the form of alum or sodium aluminate. Lime treatment involves use of single-stage or two-stage systems.

TABLE V
CHEMICAL SYSTEMS

A Iron

Ferrous Chloride-Base-W/O Polymer

Commercial or Waste Pickle Liquor	Lime or Sodium Hydroxide Polymer
Ferric Chloride - W/O	

B Aluminum

Alum or Aluminate - W/O Polymer

C Lime - W/O Additives

1 or 2 stage

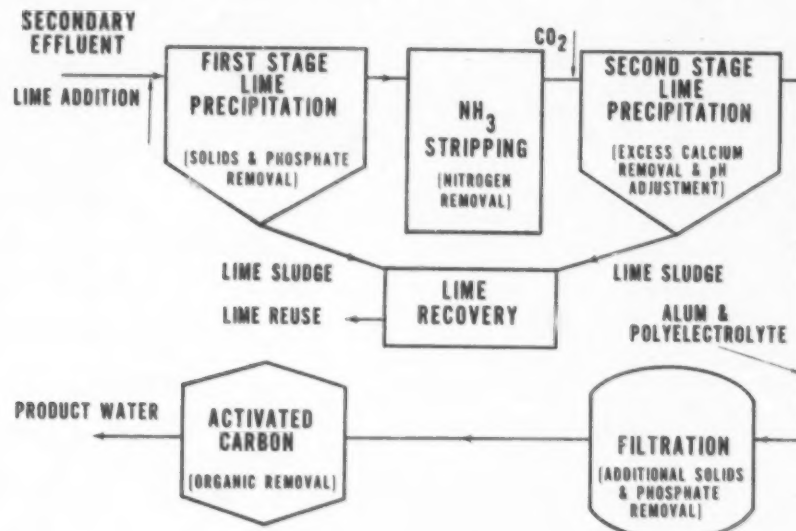
TABLE VI

FACTORS AFFECTING CHOICE OF CHEMICALS

- 1 Influent Phosphorus Level
- 2 Effluent Discharge Standard
- 3 Wastewater Characteristics (Alkalinity, etc.)
- 4 Plant Size
- 5 Chemical Costs including Transportation
- 6 Sludge Handling Facilities
- 7 Ultimate Disposal Alternatives
- 8 Other Processes Utilized

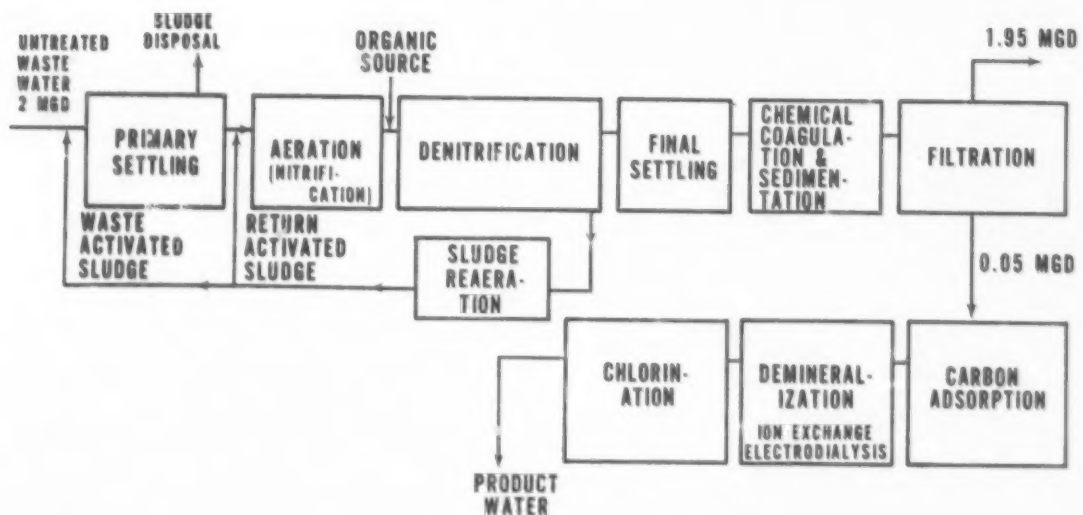
- 10 Phosphorus can be removed from raw sewage by the addition of iron, lime, and polymers. Iron salts such as ferrous chloride are used at dosages from 1 to 2.5 mg of iron per mg of soluble phosphate. Chemical costs are about 1.5¢/1000 gal. Total costs are affected by the reduced load to secondary treatment units and will be determined from current studies at three plants. The PEP system or Phosphate Extraction Process marketed by Dorr-Oliver employs lime precipitation in primary tanks.

FIGURE 2
TERTIARY TREATMENT INCLUDING CHEMICAL NUTRIENT REMOVAL



SOUTH TAHOE WATER RECLAMATION PLANT - 7.5 MGD

FIGURE 3
COMPLETE CONVENTIONAL AND TERTIARY TREATMENT

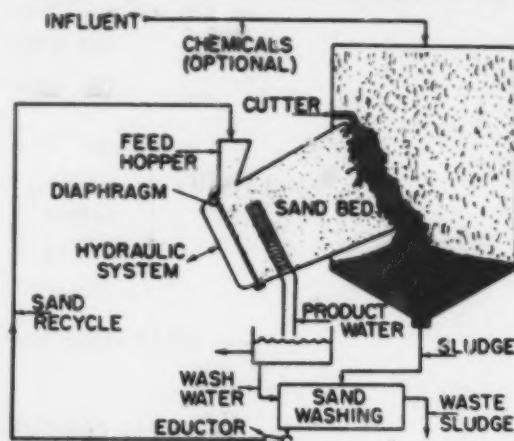


RESEARCH AND DEVELOPMENT STUDIES AT SANTEE, CALIFORNIA

- 11 By mineral addition to the aerator, phosphorus concentration in activated sludge process influent can be reduced from 10 to 2 mg/l or less by adding 1 to 2 parts of aluminum for each part of phosphorus. Chemical costs are about 3¢/1000 gal. for sodium aluminate. Costs including amortization of chemical feeders and maintenance are 4 to 5¢/1000 gal.
- 12 Results of the full-scale study on mineral addition at Pomona, California. For use of sodium aluminate, overall phosphorus removal on unfiltered samples varied from 78 to 90 percent over an Al:P ratio of 1:1 to 2:1. Slightly better removal was obtained with alum. Ninety percent was obtained at an Al:P ratio of 1.4. A deterioration of effluent quality in terms of turbidity occurred. The problem was solved by the addition of 2 mg/l of polymer.
- 13 Tertiary clarification can be accomplished by use of lime or alum. Overflow rates for lime precipitation are about 1500 gpd/sf for single-stage and 1000 gpd/sf for 2-stage. Lime dosage is dependent on the alkalinity of the water, pH, and the degree of removal required. Single-stage treatment is practical for hard waters at dosages of about 300 mg/l. Soft waters generally require 2-stage treatment at dosages as high as 400 mg/l. Cost of lime at 300 mg/l is about 1.75¢/1000 gal. Economics of lime recalcination are dependent on disposal methods available.
- 14 Tertiary clarification with alum is accomplished with an aluminum to phosphorus ratio of about 2. If influent phosphorus concentration is 8 mg/l, alum cost is about 4¢/1000 gal. Overflow rate used is about 700 gpd/sf. Approximately twice the clarifier surface area is required as compared to lime. Sludge produced is voluminous and difficult to dewater. Recovery and reuse schemes are being investigated but no practical solution has been divulged to date.
- 15 The Moving Bed Filter is a new solids and phosphorus removal technique. The Application of this concept for phosphorus removal using alum is being investigated. A schematic diagram of the Moving Bed Filter. The unit is basically a sand filter. As the filter surface becomes clogged, the filter

media is moved forward by means of a diaphragm and a clean surface is exposed. The sand and accumulated solids are separated by washing and the sand is reused.

FIGURE 4
BASIC CONCEPT OF MOVING BED FILTER



III COSTS OF ADVANCED WASTE TREATMENT

- A Capital costs for advanced waste treatment processes for a 10 mgd plant are as follows: For comparative purposes, cost of a 10mgd activated sludge plant is about \$3,600,000.

Microscreening	\$ 250,000
Filtration	440,000
2-Stage Lime Precipitation	720,000
Lime Recalcination	640,000
Ammonia Stripping	740,000
Granular Carbon Adsorption	1,600,000

- B Total costs for conventional plants and projected costs for some tertiary processes are shown here. Costs are

expressed in cents per 1000 gal. and include amortized construction, operation, and maintenance. For a 10 mgd plant, costs for second treatment are 11 cents compared to 7.2 for coagulation - sedimentation-filtration, 8 for granular carbon, and 14 for electrodialysis. Cost of tertiary treatment for removal of nutrients, organics, and inorganics is estimated at 26 to 30 cents/1000 gal. Judged by current standards, costs for tertiary treatment may seem high. However, with the higher degree of treatment, the reclaimed water becomes salable for reuse applications. For water reuse this financial burden would be reduced. Further the operations included in physical chemical water renovation are more amenable to manual or automated process control, sludge is more adaptable for dewatering and disposal and equipment space requirements are reduced.

IV IMPROVEMENTS IN CONVENTIONAL PROCESSING

- A A full-scale plant study on use of pure oxygen in the activated sludge process has been conducted at Batavia, New York under contract with Linde Division of Union Carbide Corporation. This 2.5 mgd plant has two parallel process trains with separate piping, clarification and return sludge facilities.

With recent developments in oxygen production and dissolution technology, oxygen is competitive with air and can be produced economically on site. This scheme is being investigated at additional locations.

- 1 Shows the oxygen dissolution system demonstrated at Batavia. This is a multi-stage co-current system. Each stage has mechanical mixers and compressors. Note that the system is enclosed in order to maintain high oxygen utilization efficiency.
- 2 This shows the test facility at Batavia. Temporary covers are installed over the existing aeration tanks. This system has operated at aeration tank detention times of 1 to 1.5 hours with BOD removals of 90 percent or more. Preliminary cost projections indicate a decrease in secondary treatment costs of 20 to 30 percent. Aerobic digestion occurs in the high solids and dissolved oxygen system resulting in an additional cost savings.
- 3 A study on the effect of flow equalization on performance of the activated sludge process is being conducted at Newark, New York. This new plant has a design flow of 2.8 mgd and an initial flow of about 1.7 mgd. One aeration tank will be utilized for equalizing plant flow with

TABLE VII

POMONA DATA ON MINERAL ADDITION: 2-mgd Plant, April, 1968

Aluminum Form	Ratio Al:P	Overall Phosphorus Removal	
		Unfiltered	Filtered
NaAl (OH) ₄	1:1	78	85
NaAl (OH) ₄	1.5:1	85	94
NaAl (OH) ₄	2:1	90	96
Al ₂ (SO ₄) ₃	1:1	80	83
	1.4:1	90	95

installation of temporary pump and piping (Figure 6). Aeration tank detention time is about 5 hours and will be varied to simulate an overloaded condition by use of temporary bulkheads. Flow equalization has the potential of improving operation of existing overloaded plants as well as new plants. With the advent of advanced waste treatment processes, the economics of flow equalization will become more favorable.

- 4 Pilot-scale studies are being conducted on application of the U-tube aeration concept to wastewater using aspirated air. The basic U-tube consists of parallel vertical pipes with a return bend. Air is introduced by means of a venturi aspirator or diffuser at the upper end of the inlet pipe. High transfer efficiencies can be obtained at depths from 20 to 40 feet. An alternate design is use of concentric pipes.

- a For application in sewer systems, potential plugging problems are reduced by installation downstream from pumping stations. Feasible locations are on the end of long force mains or in the drywell of pumping stations with short force mains. For such systems, headloss through the aspirator and U-tube can be considered in pump design. Compressed air can be utilized in existing systems where sufficient pump head is not available.
- b For post aeration of secondary effluent, sufficient head is normally available during periods of low flow in receiving streams when dissolved oxygen levels are more critical.

TABLE VIII

ESTIMATED UNIT COSTS FOR WASTE TREATMENT PROCESSES

CONVENTIONAL PROCESSES	SIZE-MGD	CENTS/1000 GALLON		
		<u>1</u>	<u>10</u>	<u>100</u>
Primary		14	7.5	5.1
Primary & Activated Sludge		20	11	8.6
<u>TERTIARY PROCESSES</u>				
Microscreening		1.8	1.5	1.2
Coagulation & Sedimentation (Lime - Phos. Rem.)		4.0	3.7	3.4
Filtration		7.7	3.5	1.6
Granular Carbon Adsorption		16	8.0	4.0
Electrodialysis		21	14	8.7

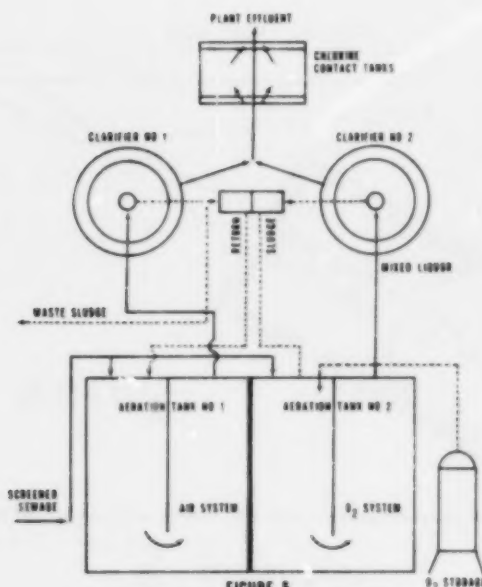


FIGURE 5
PURE OXYGEN STUDY BATAVIA, NEW YORK

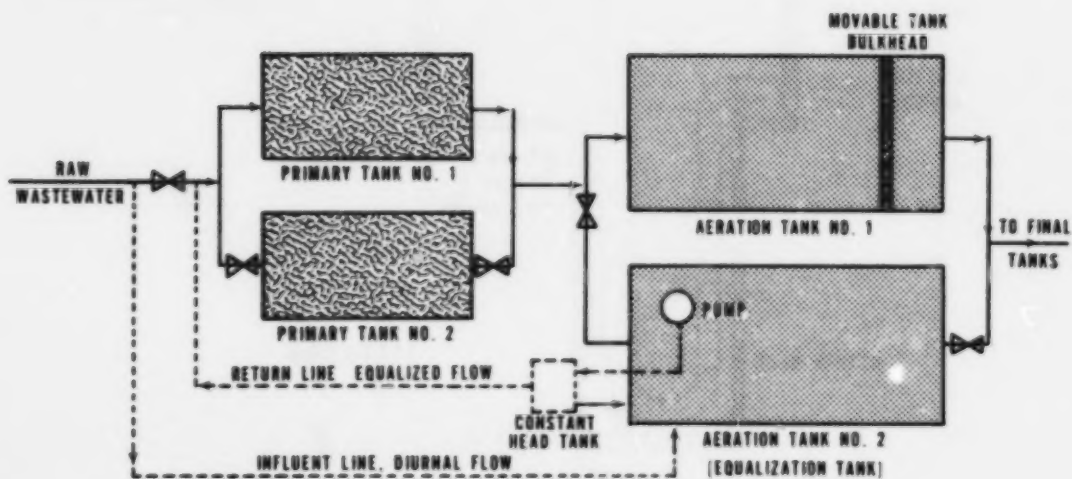
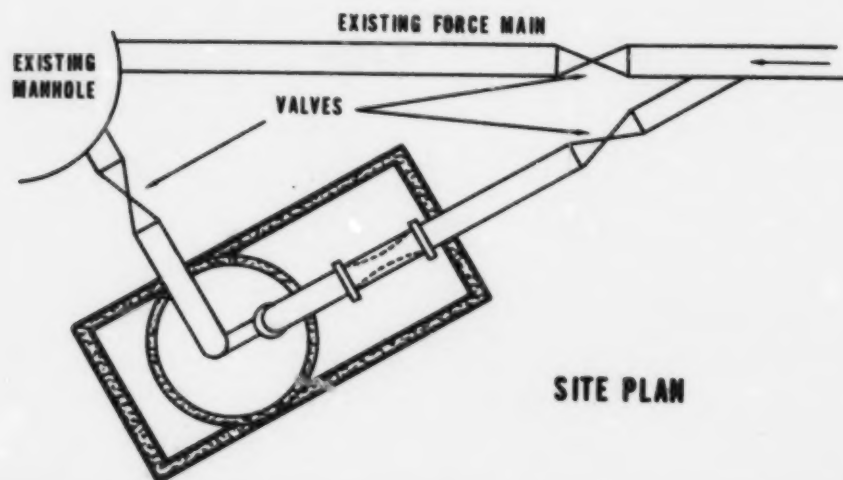
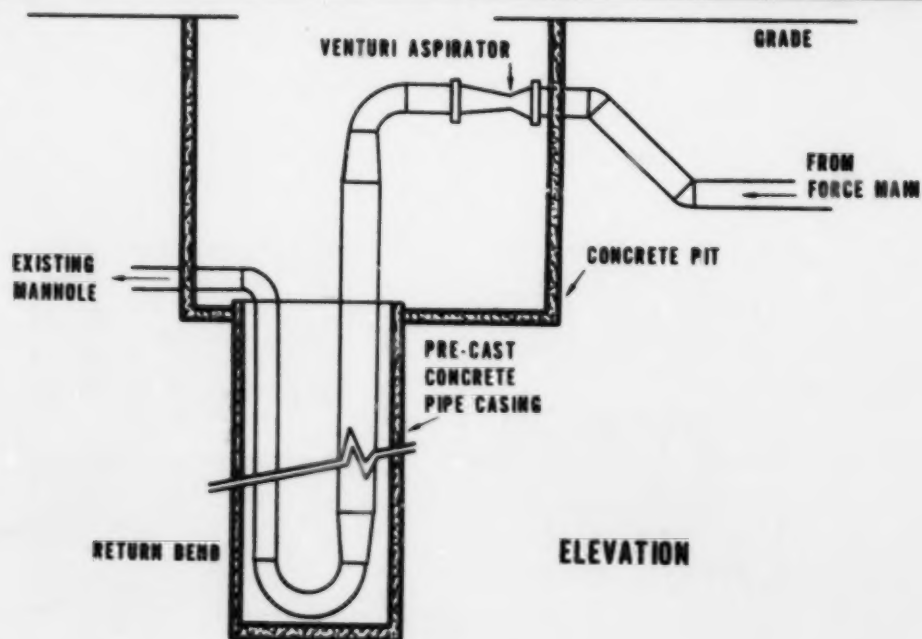


FIGURE 6
FLOW EQUALIZATION STUDY
NEWARK, NEW YORK



SITE PLAN



ELEVATION

FIGURE 7 FORCE MAIN U-TUBE APPLICATION

- c Three grant studies on in-sewer treatment for reduction of corrosion and septicity are being conducted. An extensive 3-year study is being conducted by the Los Angeles County Sanitation Districts on the parameters affecting sulfide generation and oxidation. Included are quantitative evaluations on rate of generation of sulfides in slime layers and the flowing stream, rate of reoxygenation through the air-liquid interface in sewers, and design criteria for aeration of force mains.
- 5 A study of in-sewer aeration methods is being conducted at Jefferson Parish, Louisiana. Methods to be evaluated include two U-tube aerators on the end of force mains, an eductor or air lift pump in a gravity sewer, and a vortex aerator and venturi aspirator installed in a force main.
 - a Air and gaseous oxygen are being injected into force mains at Port Arthur, Texas. Use of pressurized aeration tanks at pumping stations is also being evaluated at Port Arthur.
- B Mathematical models are or have been developed for conventional and advanced processes. Models developed are sets of computational procedures from which the cost and performance of a process can be computed when certain information is supplied as input. The input supplied is the stream vectors of flow and characteristics of all influent streams to the process and decision parameters which specify the desired mode of operation and basis of design. The program output includes equipment sizes, the magnitude of minor streams such as chemical requirements, and the stream vectors for all effluent streams. Capital cost, operating and maintenance cost, and debt service are also computed.

Models for the activated sludge process were developed at the Advanced Waste Treatment Laboratory in Cincinnati. Research Contracts have been awarded for models for final clarification, coagulation and sedimentation, fluidized bed and multiple hearth incineration, ammonia stripping, electrodialysis, and ion exchange.

V DESIGN MANUALS

- A We have recognized the need for improved methods of dissemination of results from research and development programs and are planning a series of design manuals. These manuals will supplement our technical seminars and publications on results of in-house and extramural projects.

The information needed by consulting engineers for design of advanced waste treatment plants is now available for some processes. However, the data are included in numerous publications, reports, and manufacturers' literature. The purpose of the manuals will be to compile available information in a form which can be readily utilized, and provide detailed information on hardware selection and system design.

- B Manuals to be developed shown here are phosphorus removal, upgrading capacity and efficiency of existing plants, and treatment of secondary effluent by granular carbon adsorption. The phosphorus manual will include chemical treatment in the primary, mineral addition to the aerator in the activated sludge process, and tertiary clarification. Upgrading existing plants will include suspended solids removal, increase in sedimentation capacity by use of tube clarifiers, and flow equalization. The manual on use of granular activated carbon will be limited to treatment of secondary effluent using pressure or gravity flow.
 - 1 Tentative outline for the design manual is shown in Table 9. It is planned to include sections on basic design considerations, a literature review of research studies and field experiences, outline of laboratory and/or pilot studies needed for design, choice of candidate processes, economic analyses of alternatives, and preliminary plant designs. This section on plant design will include typical plant layouts, conceptual plans and specifications, and special design requirements including corrosion control, valve selection, piping design, control systems, and chemical handling. Personnel requirements for plant operation and maintenance will be included.

TABLE IX

BASIC OUTLINE FOR DESIGN MANUALS

- A Basic Design Considerations
 - B Literature Review - Research Studies and Field Experiences
 - C Outline of Laboratory and/or Pilot Plant Studies Needed
 - D Choice of Processes for Further Study
 - E Economic Analyses of Alternatives
 - F Preliminary Plant Designs
 - 1 Plant Layout
 - 2 Conceptual Plans and Specifications
 - 3 Special Design Requirements - Corrosion Control, Valve Selection, Piping, Chemical Handling, etc.
 - G Personnel Requirements
-
- 2 Conventional treatment plants have historically been designed in many cases on the basis of flow, BOD, and suspended solids without the benefit of laboratory and pilot plant studies. This approach is not considered feasible for some advanced processes. The manuals will include the necessary lab and pilot plant studies for process selection and design.
 - 3 Design of conventional plants has involved criteria such as lbs. of BOD per 1,000 cu. ft. of aeration tank volume and cu. ft. of air per gallon. A different set of parameters will be required for advanced processes.

TABLE X

DESIGN PARAMETERS
UPGRADING EFFICIENCY OF
EXISTING PLANTS

MICROSCREENING

- Choice of Fabric and Configuration
- Washwater Requirements

FILTRATION

- Choice of Upflow, Downflow, Moving Bed, or Gravity Flow
- Media Selection and Depth
- Filtration Rate - GAL/ MIN/SQ FT
- Backwash Rate - GAL/ MIN/SQ FT

SEDIMENTATION - TUBE CLARIFICATION

FLOW EQUALIZATION

- Basin Sizing
 - Mixing and Aeration Requirements
-

- 4 Design parameters for granular carbon adsorption systems are shown in Table 11. These include choice of pressure, gravity flow, downflow, upflow, or moving-bed contact systems. Design parameters for systems are carbon particle size, superficial linear velocity, contact time, carbon capacity, and carbon loss on regeneration. Contactor design involves selection of number of stages, and use of concrete or rubber-lined steel vessels. Piping selection and design is more complex because of abrasive materials.

- 5 Design parameters for microscreening include choice of fabric and configuration, drum speed, and washwater requirements. Filtration parameters include choice of downflow, upflow, moving-bed, and gravity or pressure systems; media selection and depth, filtration rate, and backwash rate. Parameters for flow equalization are basin sizing and mixing and aeration requirements.
- 6 Design of phosphorus removal systems involves choice of chemical addition point, choice of chemicals, and ultimate disposal alternatives. Hardware selection and design includes control systems, chemical feeding and storage, mixing and flocculation, solids separation, and solids concentration and disposal.

VI OTHER ADVANCED WASTE TREATMENT PROJECTS NOW BEING PLANNED INCLUDE:

- A Development of Phosphate-free Detergents
- B Development and Demonstration of Instrumentation for Automatic Control of Plants
- C Additional Studies on Distillation

In summary, costs of tertiary treatment will be high by present standards. Greatly increased expenditures will be required to eliminate pollution of our lakes and streams. Water reuse by industry and for nonpotable purposes will be necessary to reduce the financial burden.

Potable water reuse by mixing with fresh water supplies is considered to be a distinct possibility in the future.

TABLE XI

DESIGN PARAMETERS

GRANULAR ACTIVATED CARBON SYSTEM

Choice of Pressure, Gravity Flow, Downflow, Upflow, or Moving-Bed Systems

Carbon Particle Size

Superficial Linear Velocity - GAL/ MIN/ SQ FT

Contact Time

Carbon Capacity - LB COD/ LB Carbon

Regeneration Loss

Number of Contacting Stages

Contact Design - Concrete or Rubber Lined Steel Vessels

Piping Selection and Design

This outline was prepared by C. L. Swanson, Research Sanitary Engineer, Contracts and Grants Activities, Robert A. Taft Water Research Center, Cincinnati, OH 45226

SMALL SCALE WASTEWATER TREATMENT SYSTEMS

I INTRODUCTION

- A Collection and treatment of wastewaters in central facilities where competent operators maintain continuous performance control is preferred.

This is not always feasible because of isolation, topography, discontinuous use and other factors. Situations favoring small treatment units include:

- 1 Highway rest areas
- 2 Remote hospitals or institutions
- 3 Work camps
- 4 Park or forest tourist areas
- 5 Small military or government installations
- 6 Suburban housing or villages

- B Size and numbers of the small plant variety are tenuous. Kugelman, Schwartz and Cohen (1) include the following:

- 1 Approximately 5,000 Package Plants have been installed in the past 20 years.
- 2 3,000 to 6,000 plants are estimated for small communities.
- 3 2,000 to 10,000 plants are estimated for parks and marinas.

- C An arbitrary upper limit of 5,000 population and/or 0.5 MGD flow was used (1) for small plant designation. Most of these plants are well below these figures ranging in size down to the single family or small crews.

- D Visuals and descriptions of commercially available equipment were obtained from manufacturers, brochures, and published information. Discussion of specific

proprietary equipment is used for illustration of representative approaches. This is not intended to present a complete listing of available equipment. Discussion of a specific proprietary item does not imply endorsement by the EPA, the OWP or other Government agency.

- II Small waste treatment systems include an unusually large variety of forms and utilize many operating principles. (2) The ingenuity and diligence of the fabricator, manufacturer, designer and operator either "makes" or "breaks" performance characteristics. Selected types will be discussed in terms of historical development, treatment objectives, and size.

- A Small units roughly may be classified into the following groups or combinations of them depending upon the major stress in treatment.

- 1 Household "inside" plumbing
- 2 Single family package units
 - a Aerobic
 - b Anaerobic
 - c Special purpose devices such as those for shipboard, military or space application.

- B Most small treatment plants historically have been based on biological stabilization in aqueous suspensions or soils.

- 1 Performance is limited in terms of:
 - a Solids, nitrogen or phosphorus removal
 - b Extreme load and flow variations
 - c Start and stop operations

- d Effects of toxic concentrations in the inflow.
- e Operational attention and fail-safe protection.

Discharges commonly are reasonably acceptable when effluent criteria are not high. Surface discharge of effluents have been banned by some local authorities.

C Physical Chemical Operations are becoming increasingly attractive for meeting higher effluent quality requirements. Coagulation, adsorption, oxidation, filtration, disinfection and other operations may be programmed for specific water reuse objectives. Among advantages are:

- 1 Design capabilities for a variety of wastewaters.
- 2 More readily automated.
- 3 Start-stop operations more controllable.
- 4 More positive removals for water reuse capabilities.
- 5 Adaptable for variable flow and load.

Certain limitations apply also:

- 1 Acceptance of the "different".
- 2 High operational & maintenance costs.
- 3 Requires more operational know how to manage a more complex operation.
- 4 Malfunction becomes more obvious when high quality water for reuse is intended.

III INSIDE FACILITIES

- A The problem begins in kitchen, laundry, or sanitary facilities. Here the dilution, the nature, the treatability, and the amount of load are determined depending on the habits,

the variety of discharge items, and the socio-economic status. Water use today may be something like this:

	<u>gal/cap/day</u>
Kitchen and potable water	7
Personal hygiene	22
Laundry	25
Toilet flushing	25
Miscellaneous	5

Items 2 and 3 are highly variable among households. Laundry use has increased tremendously with changes in habits and equipment but job laundries are popular. Toilet flushing tends to be the largest and most consistent water use in the home.

B The thundermug or pot was a prominent fixture in the featherbed era. It was simple and effective. It also required care in use and disposal. It's a curio today.

- 1 Sir Thomas Crapper's device changed customs to water carriage about 100 years ago. Water use soared.
- 2 Water saving devices in the home are directed toward toilets, shower flow control and laundries.
- 3 Shallow trap toilets may require 3.5 gal/flush as compared with the conventional 5 to 6.
- 4 Individual incinerator, recycle toilets are available for use where water carriage is impractical. The Monogram Industries recycle toilet is manufactured for aircraft use. An initial charge of about 8 gal. of water may serve for about 160 uses with disinfection and decolorizing for each recycle. The "dump" volume may double original charge volume.
- 5 The Liljendahl vacuum system uses air and about 1/2 gal. of water per flush as a transport system. A waste

receiving tank with a vacuum pump are required. This has been used for hotels and other large buildings in Sweden and the Carribean Islands to reduce water lift or collection plumbing.

IV SINGLE FAMILY "OUTSIDE" EQUIPMENT

A The privy, Chick Sales, backhouse and other colorful terms were an essential item in our developing nation. They are still with us along roadways, parks and some dwellings. Generally they were located down wind and remote from habitats which complicated relief in bad weather.

B Individual home package plants have been on the market since about 1955; 20,000 to 30,000 units may be in operation. About 12 different companies market home aerobic units. Cost may vary from \$800 to \$1600 per unit. Aerobic stabilization provides fairly acceptable discharges but occasional solids "burping" causes difficulties. Subsurface disposal of effluents are required by some regulatory agencies. Filtration and disinfection facilities for the effluent raises unit costs by about 50%.

1 The Yeoman's Cavite home unit is about 4.5 ft. wide, 6.5 ft. long and 5 ft. deep. Air is supplied by a 1/2 HP mechanical aerator. A settling basin is attached. Air circulation provides for sludge return.

A typical home site installation is shown in the lower right of the picture. Below grade installation in garage or basements may be used.

2 The Chromoglass unit is constructed of plastic and fiberglass (Cromar Company) with a spherical shell of about 6 ft. diameter.

Sectionally the unit consists of an inner core receiver with turbulent mixing. The aeration chamber surrounds this. Effluent flows through a filter to the outside ring. A baffle protects the outlet pipe.

3 Many more devices are available, new devices appear as commercial interests become more involved. As suggested earlier capital maintenance and operational costs are high. Operational control commonly is negligible; solids and effluent disposal often are not ideal. Failsafe provisions may be inadequate; if so, the units become objectionable. Policing numerous installations becomes next to impossible.

Improving performance is possible with regular checks of operation and maintenance, effluent quality, and withdrawal of a suitable proportion of solids regularly. Provisions for clarifier scum control, coagulant addition when needed and flow equalization will help. Prompt correction of outage is important. Standby power is advisable. These provisions will make a good unit perform consistently under favorable conditions. The individual homeowner rarely is willing or able to provide the necessary services. It's easier to forget.

V SEPTIC TANK - SOIL DISPERSION SYSTEMS

A Septic tank installations are the most common individual household treatment systems in fringe areas. About 1.4 million new units have been installed since 1960, probably 16 to 17 million are in use.

The septic tank part of the system essentially is a solids-liquid separator with some low-rate digestion. Liquifaction of solids is prominent. Its major function is to prevent gross scum and solids discharges from plugging the soil dispersion field. Most of the stabilization occurs in the soil. Unfavorable soil structure, overloading and inattention are frequent problems.

B A typical home installation schematic includes collection lines from the house, septic tank and distributor for liquid discharges to soil dispersion lines.

- 1 A section of the septic tank with inlet and outlet baffles and access manholes are shown. Nominal size for one family is 500 to 1,000 gallons. Accumulated solids must be pumped out at 3 to 5 year intervals.
 - 2 The soil dispersion piping must be laid in leveled and prepared trenches. The laterals must be surrounded by clean graded gravel with careful backfill to prevent filling laterals or plugging lateral openings. Coarse aggregate should be provided under the laterals to permit discharged solids to work downward while liquid moves outward.
 - 3 A seepage pit or cesspool is sometimes used in place of the soil dispersion fields.
- C Septic tanks and soil dispersion are limited by acceptance of the soil for the discharge liquid. Light soils preclude effective use or require long lines and carefully prepared trenches. Ground water contamination is a constant danger. Nearby wells often are contaminated. If excessive solids plug the dispersion field, liquid has to go upward or backward with obvious effects either way.

VI ACTIVATED SLUDGE PACKAGE PLANTS

- A More than 25 companies are listed in the WPCF journal that supply multiple family activated sludge package plants. They may be factory assembled in standard sizes or erected on site for larger units.
- B Basically there are two main types of units:
- 1 The extended aeration plant scheme uses an aeration section for sludge and influent mixtures with a holding time of about 24 hours. This is followed by a clarifier for liquid-solids separation and sludge return to the aeration inlet.
 - 2 The contact stabilization plant configuration utilizes aeration of sludge and influent mixtures for 1 to 4 hours,

followed by clarification and effluent discharge, the sludge or solids concentrate is stabilized by separate aeration before recycle.

- 3 Although the same scheme is used in most of these package plants, each fabricator or manufacturer uses a variety of layouts (2) depending upon equipment, concepts, preference and requirements.
 - 4 Installations may be brought in by truck erected above ground, or as in this case below ground level. (50000 GPD unit) Other units are fabricated of concrete and steel.
 - 5 In theory a load of 1 lb. BOD (household wastewater) will require about 0.5 lbs. oxygen to produce about 0.6 lbs. of cell mass. Long term aeration results in endogenous oxidation of initial cell mass to form carbon dioxide, water, nitrates and sulfates. Residual solids may be reduced from 0.6 to about 0.12 in process.
- a BOD₅ data represent a quantity/time or rate estimate expressed in terms of oxygen use. Generally this estimate is part of the load as exerted in treatment.
- b Accumulated residual solids represent a continuous buildup that eventually is discharged via the effluent. A change in solids settleability or flow increase usually results in periodic discharges containing gross amounts of suspended material.
- c Suspended solids include most of the effluent contamination. Soluble BOD generally is low. BOD₅ is a very poor index for suspended material and tends to grossly overrate treatment performance in terms of later events.
- d Most extended aeration effluents are highly nitrified at or below design loading.

C Design criteria traditionally have been based upon BOD_5 data or population equivalent at average flow and concentrations.

- 1 Aeration tanks commonly are designed for 12 to 24 hours detention, a loading of 15 - 25 lbs. BOD_5 /1000 cu. ft. and an air supply capacity of 1500 to 2000 cu. ft. of air/lb. BOD_5 loading.
- 2 Settlers or clarifier units are designed for approximately 4 hours detention, 200 to 600 GPD/sq. ft./day surface overflow rate, 600 to 3000 GPD/ft. of weir overflow rate and a sludge return capacity of 3 times average flow.
- 3 Performance on the basis of the usual inattention ranges from 33 to 93% BOD_5 removal - average 86, suspended solids removals range from 96% to a net increase. The average was 62%. This is not impressive but it can be improved by knowledgeable operation.

D Trickling filtration units usually are not considered as package plants even though installations are very numerous, serve similar functions, and similar limitations. They are very popular among small communities. They usually are constructed on site of concrete or steel with slime growth support via rock, slag, plastic or wood.

- 1 The Bio-disc or Rotating Biological Contact Unit Autotrol Corp., Allis Chalmers, is packaged. A series of discs mounted on a shaft are rotated slowly with partial submersion in wastewater. Slime growth attaches to the disc, wastewater is picked up each turn and exposed to air throughout about 3/4 of each revolution time for stabilization purposes. More than 400 of these are in use in England.
- 2 The uncovered unit shows tankage, discs for two-stage operation, bucket feed, and clarification compartment.

- 3 The Biodisc unit may be used in conjunction with an equalization and septic tank for liquid and solids stabilization.

VII PHYSICAL - CHEMICAL TREATMENT

Physical chemical treatment such as settling and oxidation have been a part of treatment since treatment began. More recently, additional unit operations have been used to enhance treatment capabilities in the wastewater field. All have been used successfully in water supply or industrial operations. The problem is to overcome tradition and to apply these in wastewater treatment to upgrade performance and dependability. They may be used to upgrade biological treatment or to replace it. The operations may be selected to produce any specified water quality.

A Biological treatment effluents commonly are not good enough to protect surface waters in terms of solids, phosphorus, and nitrogen control. Disinfection is a well known chemical treatment commonly required now.

- 1 This Basil Switzerland small plant was upgraded by coagulant addition to improve solids and phosphorus removal. Additions include the red spheres for chemical storage, dosing pumps and lines also in red.
- 2 Nitrogen phosphorus and solids removal from anaerobic digester supernatant is the objective for this trailer mounted package plant. (FMC Corp.). Free CO_2 is stripped, coagulant added (right) the liquor settled (center) and the supernatant pumped to packed towers for air stripping of ammonia (left). This is a side-stream treatment designed to relieve the very troublesome digester supernatant recycle problem.
- 3 Coagulation clarification (with or without filtration) and carbon adsorption are feasible for start-stop operations, toxic loads and for cleanup of treated

effluents. Carbon treatment is common in water supply treatment; its moving into wastewater treatment for good reasons.

- 4 Upgrading secondary effluents is the target for the Neptune Microfloc Reckla-Pak plant. Package units are available in a size range from 12000 to 50000 GPD. The manufacturer claims 98 - 99% BOD and Susp. solids removal. Tube settlers are included.
- 5 Pressure filters, gravity sand filters and membrane filters likewise are available for particulate removal. Microstrainers add to the suspended solids removal operational choices.
- 6 The Dorr-Oliver Plant IOPOR System at Pikes Peak is an interesting development in package plants; activated sludge treatment followed by ultrafiltration are included for treatment of highly variable loading. Very good removals are obtained although color seems to be a problem. Performance depends upon flux life of the Ultrafiltration membrane. Capacity of the membrane initially is reasonably good (30 GPD/sq. ft.) then decreases. This unit was used during part of the 1970 tourist season. More experience will be available during the full season in '71. Daily membrane washing is likely to keep delivery above 7 GPD/sq. ft. for 6 months.

VIII SPECIAL PURPOSE PACKAGE SYSTEMS

- A U.S. Army MUST (Medical Unit - Self contained - Transportable). The Garrett Corp. developed the package that can be air dropped to provide incineration of human waste, garbage and refuse, and for treatment of laundry or bathing waters for reuse.
 - 1 A small volume of flushing water is used in the toilet system. Wastes and wastewaters are incinerated in the adjacent unit.

- 2 The treatment room schematic shows treatment equipment for screening, precipitation, floatation and chlorination. Demineralization may be provided separately.

B Marine treatment systems are packaged for protection of harbors and inland water.

- 1 The Fairbanks-Morse system treats toilet wastes for about 175 men in a 6 x 4 x 5 ft. unit using chlorination floatation and incineration.
- 2 The Westinghouse Puripac system includes comminution, electrolytic floatation, chlorination and digestion or incineration.
- 3 The cited examples of Marine systems are not intended for or will provide for high quality discharges. Dissolved solids removals are low.

IX SUMMARY

Many different types of treatment systems have been mentioned for package plant application. Many more are available commercially. Basic units may provide a reasonably good discharge part of the time. With appropriate operating attention to regular solids draw down, maintenance, subsurface disposal of effluent and operating continuity they will provide good solids removal consistently. It is possible to tailor package units for producing excellent reuse water predicably via use of coagulation, adsorption, clarification, filtration, deionization, and disinfection. Physical chemical operations are more positive, more versatile, and more specific than biological treatment but it will be more expensive to produce consistent high quality reuse waters.

ACKNOWLEDGMENT:

This outline is based upon previous material supplied by C. L. Swanson, EPA, OWP, AWTRL.

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This outline was prepared by F. J. Ludzack, Chemist, National Training Center, OWP, EPA, Cincinnati, OH 45226.

SECTION III

This section includes common equipment found in treatment facilities and factors pertinent to obtaining the best performance during use.

	<u>Outline Number</u>
Interceptors, Pumping Stations, Outfalls	18
Screening-Methods and Purposes	19
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Flow Measurement Devices	22
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Sedimentation Tank Equipment	24
Practical Aspects of Oxygen Transfer	25
Process Equipment for Sludge Handling, Digestion and Disposal	26
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Sludge Combustion	28
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INTERCEPTORS, PUMPING STATIONS, AND OUTFALLS

I INTRODUCTION

The session will be broken down into three main sections: a) Interceptors, b) Pumping stations c) Outfalls. Each of the sections is a full subject within itself, but they are inter-related insofar as this presentation.

A Interceptors

1 Purpose

An interceptor transports waste from a combined sewer to the treatment works. This is a short definition of the purpose, but the interceptor has two major parts:

- a Connections from the combined sewer system
- b Main interceptor itself

2 Design

- a Sizing. In the past, interceptors have been designed by rule of thumb; i. e., three times the normal dry weather flow. Today we are taking a new look at interceptors. Although the standard rule is three times the normal dry weather flow, we must gage each sewer to be intercepted, to find the following:

- 1) The flow characteristics
- 2) The strength characteristics

- b Example. With a low strength, there is no need to intercept three or four times, as long as the BOD is within the 5 - 25 ppm range. Where a high strength sewage is found, we may have to intercept six or seven times the normal flow.

- c It is also important today to know the characteristics of the combined sewer, both as to flow and as to strength.

- d It is important to use the interceptor to capacity during storms to cut down sources of pollution from overflows.

- e Methods of interception within combined sewer

- 1) In all cases, a dam must be placed across the combined sewer to divert the flow.
- 2) The leaping weir type of interception made by a short rise in the combined sewer and a bottom drop for normal sanitary dry weather flow. During a storm, the velocity of the water causes the water to pass over the bottom drop and onto the stream.
- 3) In the side outlet, a prepared channel diverts the flow from the main channel to the side outlet.
- 4) Regulator

- a) The regulator can be manually pre-set to take a certain flow, or an automatic float type operation when the flow reaches a certain height. In the combined sewer, the float closes the interception gate and all flow goes to the stream.

- b) The constant type flow automatic regulator

- c) In either case, the flow through the automatic regulator may be controlled by flow in the combined sewer, or may be controlled by the flow in the interceptor.

- 5) Automatic valves, hydraulically operated

Again, regulated either by the combined sewer or the interceptor, or from a distant point by telemetering.

- 6) The grating connections are becoming extinct, due to the fact that they need constant maintenance and cleaning. In theory, they are supposed to work, but in practice they do not.
- f More and more communities are taking to the system approach through computer and telemetering systems, in order to maintain a high flow in the interceptor.¹
- g The flow may go as high as 500 mgd rate in an 11 foot diameter sewer, which is not uncommon and even we in Cincinnati have box conduits of 20 x 27 feet with a normal dry weather flow of from 8 to 10 million gallon.
- h The strength will vary, and especially the strength during storms will vary considerably.
- i The treatment works The effects of plant loading during storms vary.
- j Connections from combined sewer to interceptor.

This is the most important part of the design. The method of transferring of the dry weather waste flow from the combined sewer to the interceptor.

- 1) Is it of sufficient capacity?
 - 2) Will it become clogged?
 - 3) Does the connection enter the interceptor on a downstream flow, so as not to interfere with the waste in the interceptor?
 - 4) Are manholes available for inspection of the intercepting devices?
- k In deep interceptor - from 20-30 feet below the combined sewer
- 1) Has the proper dispersion of velocity created by the drop to the interceptor been taken care of?

- 2) In the manhole, is there a side step at the interceptor level for a man to stand on?
- 3) Are there manhole steps in the sewer over 6 - 8 feet in depth?

It is not the practice today to use manhole steps, but rather to use ladders, rope or metal, or bosun chairs supported from trucks.

- 4) On deep tunnel work, are there provisions for sight holes for alignment.

Sight holes are also to be provided for pumping concrete in tunnel work.

- 5) Are the curves gentle and of sufficient radius that tunnel machines and boring machines can be used? This will reduce the cost per foot of tunnel.
- 6) On the use of air, are sufficient specifications provided for the Industrial Commission's rulings for the use of air, for each state, all different?

3 The future

Any design of interceptors from now on should consider:

a The storage areas

- 1) Side chambers
- 2) Underground
- 3) The stream

But it is to be noted that in all storage areas there must be methods for cleaning same.

B Pumping Stations

1 Small package units

- a Up to 500 - 600 gpm. Normal in the 50 - 200 gpm range

- b Used in subdivisions, due to the value of land today
- c Used on intercepting lines of long distances on flat terrain
- d From a design standpoint, cost of a package pumping station is cheaper.
- e From a construction standpoint, ease in installation -- normally two pads: one for pumping station, and one for wet well. Connect up.
- f Telemetry provisions for power failure and wet well overflow
- g Deep units should have elevator placed on side rails of ladder.
- h Injector type. It is more practical to place electric motor and compressor up near the surface to reduce condensation problems.
- i Proper humidity controls and meters should be incorporated into station.
- j Where necessary, driveways should be provided so that trucks may pick up for removal of equipment.

2 Large Pumping Stations

- a Elevators are a necessity in deep pumping stations. It is proper for the operator to walk down each level of the pumping station, inspecting equipment, and ride up on the elevator.
- b Provisions for telemetry
- c Provisions for humidity control
- d A very necessary item: areaway, for removal of equipment.

3 Inspection

From an operational standpoint, the small package plant should be inspected in accordance with the experience of the pumping station, at least once a week.

In large pumping stations, it is good practice to inspect pumping stations at least once a day and, sometimes, three times a day.

C Outfalls

- 1 Purpose: To convey treatment waste from the treatment works to a receiving body.

2 Types:

- a Above discharge -- open end pipe. Not good. No dispersion and channelization in receiving body.
- b Straight discharge on the bottom of the stream. Better than above discharge, but little dispersion, channelization.
- c Side outlet -- bottom discharge.
 - 1) Place on bottom of receiving body.
 - 2) Outlets located downstream side.
 - 3) Can give maximum dispersion into receiving body.
 - 4) The quicker effluent is dispersed into receiving body, the quicker it is received into the stream and becomes impotent to lowering the quality of the stream.

#1

Excerpts from

**"STORM AND COMBINED SEWER POLLUTION CONTROL
DEMONSTRATION PROJECTS"**

United States Department of the Interior

Federal Water Pollution Control Administration

March 1, 1968

cf Reference 1

TITLE OF PROJECT:

PROJECT SITE:

Page 1	Dispatching System for Control of Combined Sewer Losses	Minneapolis-St. Paul, Minnesota
Page 4	System Monitoring and Remote Control	Detroit, Michigan
Page 9	Duwamish River - Elliott Bay Storm Water Control System	Seattle, Washington
Page 12	Systems Approach to Combined Sewer Storm Water Overflow Pollution Abatement	Shelbyville, Illinois
Page 13	Wards Island Water Pollution Control Plant Ponsar Flow Regulating Siphon	New York, New York
Page 24	The Problems of Combined Sewer Facilities and Overflows in United States Communities	Chicago, Illinois

#2

REFERENCE

Manual No. 9, Water Pollution Control Federation; or American Society of Civil Engineers Manual of Engineering Practice No. 37, Design and Construction of Sanitary and Storm Sewers.

This outline was prepared by A. D. Caster, Director, Division of Water Pollution Control, City of Cincinnati, Ohio 45204.

SCREENING - METHODS AND PURPOSES

I GENERAL

Screening of wastewater is conducted as a preliminary treatment step to remove large suspended materials which may be harmful to other plant operations.

II METHODS

In general, screening operations are of two types:

A Screening

Screening and removal of solids for subsequent disposal (usually by burial) is generally achieved by using:

- 1 Bar screens or bar racks
- 2 Drum screens
- 3 Vibrating screens
- 4 Disc screens

The simplest form of screening, the bar rack, consists of parallel vertical bars inclined to the flow in order to facilitate hand cleaning. This is accomplished by means of a long-handled rake.

In some installations, fixed trash racks are movable and can be raised for cleaning. In this case, dual channels are needed in order to have one rack in service at all times.

Mechanical cleaning is done by moving rakes attached to an endless chain. (Figure 1)

Drum and disc screens are the most widely accepted screens for domestic sewage. Sewage flows through the screen depositing material on the outside. As the screen rotates, material is brushed or jetted off into a screen pit where it is removed by a bucket elevation. (Figures 2 and 3)

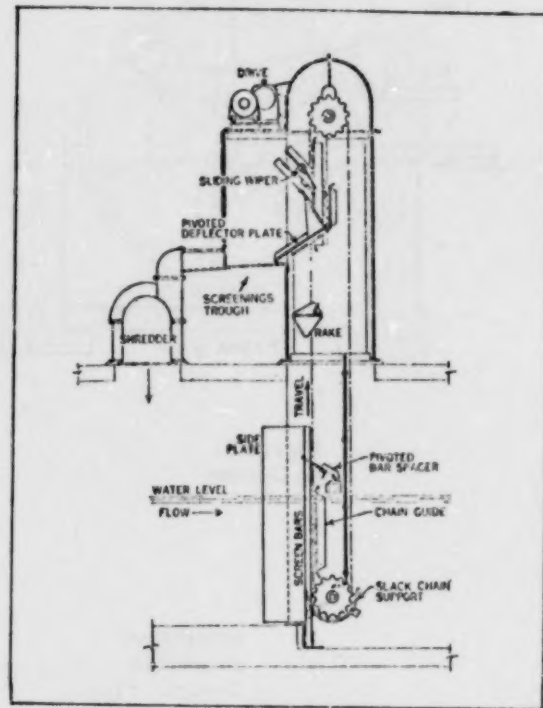


Figure 1: Vertical Section of Bar Screen and Mechanical Rake.

Vibrating screens have received much favorable acceptance in industrial applications for removal of organic solids which would otherwise drastically overload the treatment plant.

Solids removal by use of bar screens is negligible. Fine screens average approximately 10 percent removal of suspended solids and are primarily used to remove fibrous industrial wastes.

B Comminution or Grinding

In cases where grit is not a problem, or following grit removal, incoming material is ground or chopped by means of oscillating cutter bars to reduce large materials to a size that can be handled in the treatment processes.

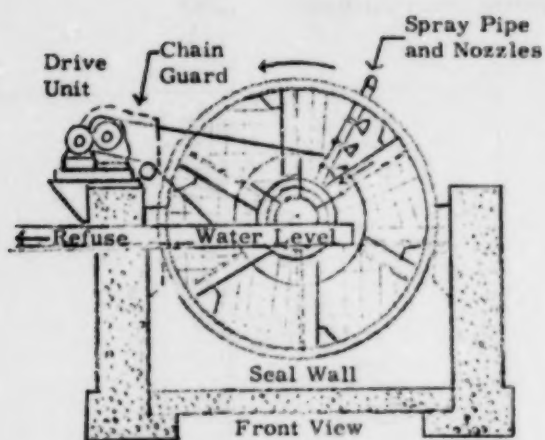


Figure 2
Disc Screen

There are three major types of equipment in general use for reducing the size of suspended solids:

- 1 The comminution consists of a rotating, cutting screen. The sewage flow passes through the screen and out the bottom end of the rotating drum. (Figure 4)
- 2 Barminutors combine the design of the bar screen with a travelling grinder which moves up and down the rack to shred the solids collected on the screen.
- 3 Grinders and shredders of varied design are available for reducing the size of solids removed from bar screens.

In addition, grinders are frequently used at the waste source to reduce the solids to an acceptable size. The home garbage disposal unit and its commercial and industrial counterpart are examples of such units.

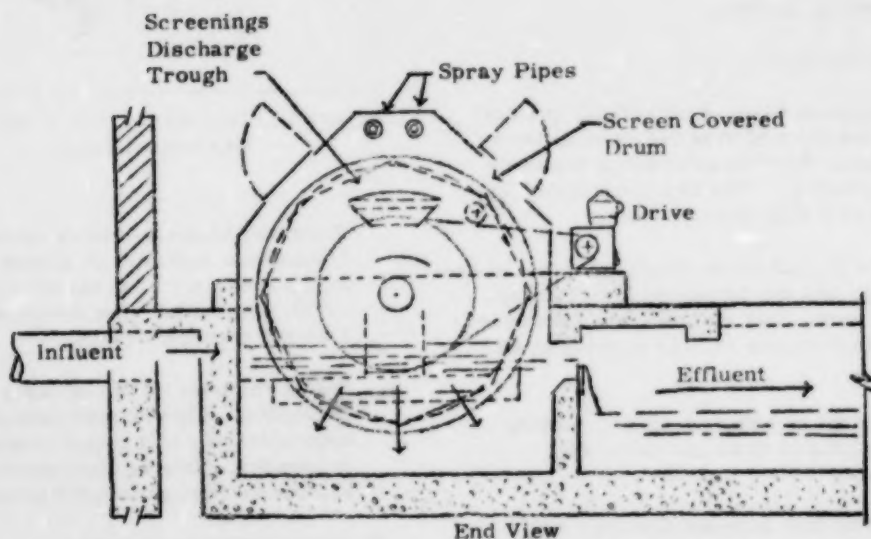


Figure 3, Drum Screen

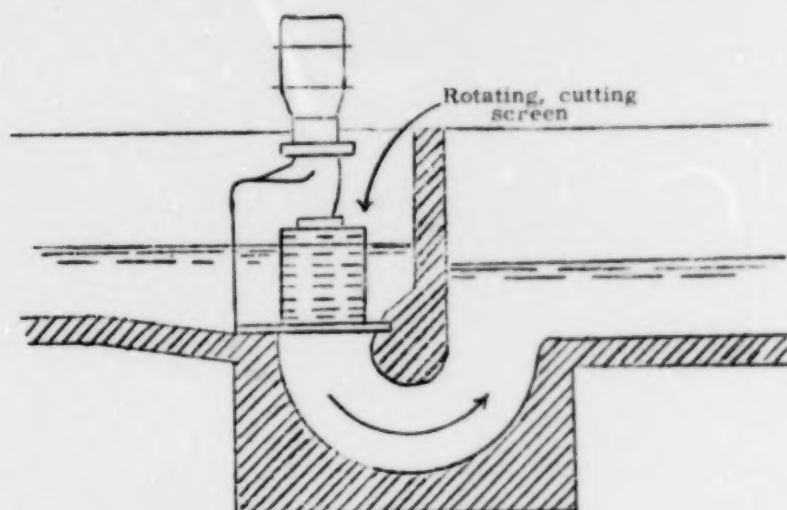


Figure 4. Cutting Screen or Comminuter

III PURPOSES

A Protection

Removal of such solids as large sticks, glass, metal, etc., protects the sewage treatment equipment from damage.

B Reduce Maintenance

Removal or grinding of large suspended solids such as rags, sticks, and certain types of commercial and industrial wastes reduces the potential of clogged pumps and pipe lines with the attendant maintenance problems.

C Increase Plant Efficiency

Reducing the size of organic solids by grinding or comminution increases surface area available to bacteria, thus improving digester efficiency.

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This outline was prepared by Lyman J. Nielson, Chief, Training, Pacific Northwest Water Laboratory, Corvallis, Oregon.

GRIT REMOVAL - PRINCIPLES AND METHODS

I GENERAL

Grit chambers are used ahead of primary treatment to remove heavy solids which may be harmful to plant operation and equipment.

Grit consists primarily of inorganic materials such as sand, gravel, cinders, glass, and silt and may include organic materials such as coffee grounds, fruit seeds, grain, rags, paper and bits of meat and vegetables. Removal of the inorganic substances in advance of pumps and treatment units prevents wear of machinery and unwanted accumulation of grit in settling tanks and facilitates the handling of sludge produced by various treatment processes.

In separate sanitary systems, grit originates in wash water from kitchens and bathrooms, from washings of floors and from illegal ground or storm water connections and from industrial processes.

In the case of combined sewer systems, in addition to the above, sand and silt enter the systems from street washings through catch basins, from damaged pipe joints and drainage from excavations.

II TYPES OF GRIT REMOVAL FACILITIES

Grit removal facilities can be classified into two types:

A Grit Chambers

Grit chambers are operated at velocities low enough to permit capture of particles of specific gravity 2.65 and 2×10^{-2} cm in diameter.

The design of grit chambers is based on reducing the velocity of incoming sewage to approximately 0.5 to 1.0 f/s for a detention time of one minute. Generally the decrease in velocity is accomplished by an increase in cross sectional area.

Depending on the range in flow, it may be necessary to provide more than one chamber in order to maintain design velocity. Chambers are also designed so that the sewage enters and leaves the chambers with a minimum of turbulence. In smaller plants where mechanical grit removal equipment is not feasible, at least two chambers are required to permit manual removal of accumulated grit. (Figure 1) As manually cleaned chambers do not produce a washed grit, a considerable amount of organic matter is included with the grit. Mechanically cleaned grit chambers are cleaned periodically by some type of collection mechanism and equipment for moving the collected grit to a point of disposal.

B Detritus Tanks

Detritus tanks are operated at a relatively constant level and produce a settled grit containing considerable amounts of organic material which must be removed from the grit before disposal. This material, or detritus, can be removed by one of the following:

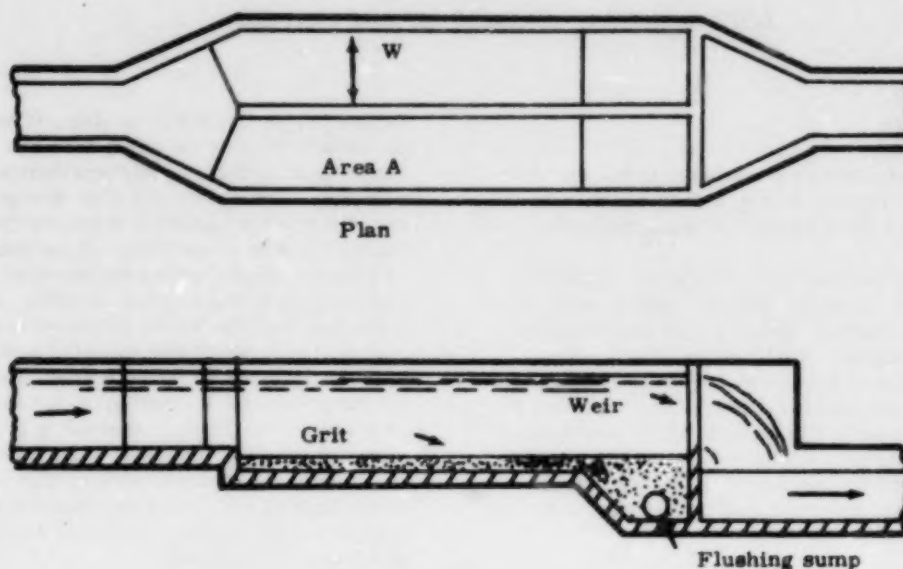
- 1 Re-suspension of the detritus by injection of compressed air.
- 2 Detritus removal by use of a grit washer.
- 3 Mechanical scraper for grit removal operated in such a manner as to flush the detritus back into the sewage flow.

III DESIGN CONSIDERATIONS

Grit chamber design requires data on volume and fluctuation of sewage flow and type and quantity of grit.

A Quality

Grit types include sand, gravel, silt, ashes, clinkers, and miscellaneous debris washed from streets. Household discharges, particularly from homes



GRIT CHAMBER
Figure 1

equipped with garbage grinders, contribute egg shells, bone chips, coffee grounds, and similar material.

B Quantity

Quantities of grit vary depending upon:

- 1 Street surface conditions
- 2 Area served by the sewer system
- 3 Climatic conditions
- 4 Types of sewer inlet structures
- 5 Maintenance of catch basins
- 6 Amount of storm water diverted from system
- 7 Sewer grades
- 8 Condition of sewer system

9 Industrial wastes

10 Use of household grinders

C Design Theory

- 1 A principal feature of grit chamber design is the use of differential sedimentation. Successful grit chamber operation is possible because of the difference in settling rates between inorganic grit particles and organic solids.
- 2 Settling characteristics of the grit particles to be removed provides the basis for chamber design. The design loading is normally expressed in surface overflow rate with depth qualified, or as linear flow velocity with length as a qualifier.

Table 1 THEORETICAL MAXIMUM OVERFLOW RATES FOR GRIT CHAMBERS

Size of Grit Particles, Diameter, mm	Average Settling Velocity of Quartz Particles (specific gravity 2.65) in Water, Fpm	Theoretical Maximum Permissible Overflow Rate for Substantially Complete Removal (Gpd per Sq Ft)		
		Specific Gravity 2.65	Specific Gravity 2.0	Specific Gravity 1.5
0.83	16.2	174,500	105,800	52,900
0.59	11.9	128,000	77,600	38,800
0.42	8.1	87,000	52,800	26,400
0.30	6.1	65,500	39,600	19,800
0.25	5.4	58,000	35,200	17,600
0.21	4.3	46,300	28,000	14,000
0.18	3.8	40,900	24,800	12,400
0.15	3.0	32,300	19,600	9,800

(Sewage Treatment Plant Design -- FSIWA Manual of Practice No. 8)

From Table 1 it can be seen that a grit chamber designed to remove 100% of minimum sized grit would also remove all larger grit particles.

The theoretical detention time is that required for the minimum size particle to reach the bottom of the tank for removal.

Other factors affecting removal of grit are:

- a Turbulence of flow in the chamber which may hinder settling.
- b Bottom scour is an important factor in grit chamber efficiency. Re-suspension and/or movement of settled grit, because of the flow velocity above a certain critical velocity, may be the controlling factor in determining flow velocity in the chamber.

3 Velocity control

Because of variations in flow, it is necessary to design the structure to maintain the design velocity.

- a Proportional weir
 - b Sutro weir
 - c Rectangular control section
 - d Parshall flume
 - e Mechanical velocity control devices
- 4 Other design considerations
- a Accessibility of chamber and appurtenances for cleaning and maintenance
 - b Grit storage in chamber
 - c Method of grit removal
 - d Arrangement of units

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PUMPS AND CONTROLS

I INTRODUCTION

- A This presentation is designed to acquaint you with the basic types of pumping equipment available today and with their applications within the sewage treatment field.
- B No attempt will be made to discuss hydraulics and other detailed quantitative design criteria for sewage pumping systems.
- C The illustrative material presented represents only a small number of manufacturers who produce such equipment. The equipment pictured has been selected only for illustrative purposes and is not intended to show preference to any particular manufacturer.

II THE NEED FOR PUMPING

- A Pumping stations should be used only where absolutely necessary within the collection and interceptor systems since routine maintenance and supervision will be required throughout the life of the project.
 - 1 Unfortunately, in many instances, adequate maintenance and supervision are not practiced, resulting in failure of the station and the subsequent generation of water pollution problems caused by sewage flows bypassed into nearby drainage courses.
 - 2 Topography will always dictate the need for some pumping stations in those situations where good sewer grades are not possible without excessive depth or where it is necessary to transfer sewage over a ridge from one drainage basin to another.
- B A variety of pumping needs exist within the sewage treatment plant including a number of specialty pumps for moving solids.
- C Since maintenance is a continuing problem inherent with any type of pumping system, every effort should be made to specify the most reliable and maintenance free equipment available within the economic limits of the project.

III BASIC TYPES OF PUMPS

- A Pumps can be classified generally into two categories: Centrifugal and Positive Displacement.
 - 1 The centrifugal is the most widely used pump due to its small size and operating flexibility.
 - a The following slides will illustrate the basic configurations of this pump.
 - 2 The positive displacement pump comes in a variety of forms including the ejector, cam, piston, and screw types. These are generally used for special applications and will be illustrated later in the presentation.

IV SELECTION OF PUMP EQUIPMENT

- A Selection of the pumping equipment best suited for the job will depend on the volume of the fluid to be pumped and its properties.
 - 1 In sewage pumping, we are principally concerned with a system not subject to clogging due to rags and other large solids.
 - 2 Consideration must also be given to the corrosive properties of sewage and the possible fouling of pumps and controls by grease and solids buildup.
- B As a rule-of-thumb, an ejector or eductor station should be used for design flows less than 100 gpm. A centrifugal pump is not ideally suited for such small flows since the small pump would be subject to clogging by large solids.
 - 1 Eductors and ejectors are both pneumatic devices that displace the sewage from a confined space with air under pressure.
 - 2 Ejectors can be obtained in various sizes up to approximately 600 gpm and heads of approximately 100 feet. Ejectors generally are not as efficient as centrifugal pumps for flows over 150 gpm.
 - 3 Eductors are used for low head applications up to 20 feet lift and flows up to 200 gpm.

- 4 The following slides illustrate various types of ejectors and eductors.

a The units pictured are all pre-fabricated factory units complete with self-contained controls and compressors. Low capacity units have a single sewage receiver or "pot" and the larger units have two for continuous filling and ejection operations.

- C Centrifugal pumps are recommended for flows in excess of 100 gpm. Due to the design of the sewage pump impellor, efficiency generally drops rapidly at heads over 100 feet and for high lift applications a series of lift stations may be required. There are two basic types of centrifugal pump stations, wet pit and dry pit.

- 1 In a wet pit station, the pumping equipment is submerged in the sewage wet well.

a The first slide illustrates a submersible pump with an integral waterproof motor.

b The second slide illustrates another type of submersible station with motors and controls above ground and pumps submerged.

c The wet pit type of station is not recommended since the most important equipment is submerged in the sewage itself where it is subject to rapid deterioration and is not accessible for routine maintenance.

- 2 The dry pit station has separate compartments for the sewage and the pumping equipment. The pumps and motors are located in a dry compartment where they are readily accessible for routine maintenance. Although more expensive than the wet pit station, it is by far the most reliable and easily maintained station available.

a The following slides illustrate some prefabricated and built-in-place dry pit station.

1) The prefabricated units are complete with self-contained motors, controls, lighting, ventilating, and de-humidifying equipment.

- 3 A relatively new development is the Spiralift Screw pump for high volume, low head application. This pump is actually a refinement of the ancient Archimedes Spiral which, in a cruder form, has been used for irrigation purposes for centuries. The pump can move large solids and debris without clogging.

- V Special pumps for moving viscous fluids are required in the sewage treatment plant for pumping sludge. Both positive displacement and centrifugal pumps are available for this purpose.

A The first two slides illustrate two common positive displacement sludge pumps. The first operates by the use of a single large piston and the second by rotating cam.

1 Care must be exercised with positive displacement pumps. If the discharge piping should become clogged or accidentally valved off while the pump is operating, serious damage to the unit could result.

B The third slide illustrates but one of several centrifugal pumps designed for sludge handling. These pumps have specially designed impellers for this purpose. This particular model is unique in that it has a built-in comminuting device for shredding any solids that might enter the pump.

C The centrifugals take up less space than the positive displacement pumps, but many operators claim that the piston operated units are the most reliable for this very difficult job. Both types have their merits and the choice may be governed by personal preference.

VI CONTROLS

A An automatic control system must be provided for the sewage pumping station that is reliable and as maintenance free as possible. The system should be one that can withstand the hostile environment of the sewage wet well and will not become stalled by grease accumulation or clogged by sewage solids and debris.

B Many types of controls are available today including floats, electrodes, and pneumatic devices. The following slides will illustrate only a few of the more common control systems in use:

- 1 The float control is the simplest and most economical control. In many instances, however, its reliability leaves much to be desired since the float is subject to grease and solids accumulation which can alter its accuracy or cause it to hang up. The third slide shows the float enclosed in a cage in the wet well. Obviously this arrangement could easily become fouled with rags and solids. In general, float controls are not recommended.
- 2 The electrode control system operates on the principal of completing an electrical circuit as the water level in the wet well rises to contact electrodes extended into the wet well.
 - a In general, electrode systems with exposed electrodes are not recommended since grease and other solids collect on the electrode and act as insulation which prevents completion of the electrical circuit.
 - b The following slide illustrates one of several acceptable electrode controls.
 - 1) In this system the electrodes are enclosed in a tube and are not susceptible to solids buildup. As the water level rises, the flexible bulb is squeezed and an enclosed electrolyte makes contact with the enclosed electrodes completing the electrical circuit.
 - c There are many other innovations based on the electrode principal but each should be evaluated with regard to its resistance to fouling by grease and solids.
- 3 Pneumatic controls are widely used and operate on the principal of back pressure actuating pressure sensitive switches. Many of these systems are very reliable and some engineers prefer them over all other types. Each system should be evaluated individually with respect to its reliability and more specifically its ability to resist clogging or fouling by grease and solids.
 - a Two types of pneumatics susceptible to frequent clogging are the compression pipe and compression bell as illustrated here. (2 slides)
 - 1) Since a constant flow of air is not introduced through the tube, the

system is not self-cleaning and can become clogged.

- b The air bubbler or air purge system is more reliable since a constant flow of air, usually about 1 cubic foot per hour, passes through the bubbler tube preventing grease and solids accumulation. A pressure sensitive device measures the back pressure in the bubbler tube and actuates the pumps at a predetermined point.

- 1) The systems illustrated are pre-wired at the factory and have self-contained air compressors for the bubbler tube.

VII VARIABLE SPEED PUMPING

- A Variable speed drives enable a station to have far greater operating flexibility than a constant speed station and a more uniform flow can be delivered since the pumping rate can be varied infinitely within the range of the pump to match the incoming flow.
 - 1 It is frequently possible to obtain better overall treatment plant efficiency from the standpoint of uniform flow since disturbances caused by the intermittent operation of constant speed pumps that "slug feed" the plant are eliminated.
 - 2 A more constant flow also helps prevent sedimentation of solids in the station wet well thus avoiding odors and hydrogen sulfide corrosion.
- B The two most frequently used drives are the magnetic and the belt drives.
 - 1 The magnetic drive uses a variable strength electromagnet connected to the pump drive shaft and separated from the constant speed motor shaft by an air gap. As the strength of the magnet is increased, slippage is reduced between the two shafts thus making the speed of the pump infinitely variable up to the maximum speed of the motor. The following two slides illustrate one type of this drive.
 - 2 The belt drive varies the speed of the pump by the use of a variable diameter pulley onto which the pump drive belt is connected. This slide illustrates one type of belt drive.

- 3 A third type of drive operates by varying the resistance across the slip rings of a wound rotor motor by means of a liquid rheostat.
- C The control systems used with variable speed drives are more sophisticated versions of the electrode and bubbler controls previously discussed.
- 1 The first two slides illustrate a combination bubbler-electrode system. The variation in wet well level is transmitted by back pressure to an enclosed vessel of electrolyte into which electrodes have been suspended. As the wet well level is varied so is the electrical resistance between the electrodes and this variable resistor in turn varies the speed of the motor.
 - 2 The third slide illustrates a typical variable speed arrangement utilizing a bubbler tube. The varying pressure in the tube is sensed by devices in the control center which in turn varies the current to the magnetic drive or causes hydraulic or pneumatic devices to vary the diameter of the pulley of the belt drive.

VIII CONCLUSION

A great variety of pumping and control equipment is available to the engineer today. Each specific application of this equipment should be carefully evaluated not only for initial cost and performance, but also for long term maintenance costs and overall reliability.

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Healy-Ruff Company
Davco Mfg. Incorporated
Marlow Pump Company
Robbins & Myers, Incorporated
Beloit-Passavant Corporated

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FLOW MEASUREMENT DEVICES

I INTRODUCTION

Flow measurements are among the important data collected as part of wastewater treatment operations. Such measurements are used to interpret treatment plant loadings, and are required to assist the operator in evaluating the overall plant condition. Flow data are also valuable in determining and/or forecasting future needs for plant expansion. If the analysis of plant operation data involves quantitative considerations, the accurate measurement of flow assumes a level of importance equal to that of the laboratory and analytical results.

In the following discussion procedures both for measurement of stream flow and waste discharges are described.

II FUNDAMENTS OF FLOW MEASUREMENT

Flow is the rate at which a volume of water is transferred, or moves through a given section, in time. Flow is commonly expressed in equation form as:

$$Q = V/T$$

where: Q is the flow rate

V is the volume

T is time

Other relationships are shown by:

$$v = l/t \text{ and } V = al$$

where: v is velocity

l is the length of section having cross-section area a

T is time

V is volume

Flow (Q) is obtained by measuring the cross-sectional area (a) and velocity (v) of the water moving past a point in the channel during a specified time period (T).

III EQUIPMENT AND METHODS

A Gauging of Streams and Rivers

1 Current Meter

The current meter is a device for measuring the velocity of a flowing body of water. The stream cross section is divided into a number of smaller sections, and the average velocity in each section is determined. The discharge is then found by summing the products of area and velocity of each section.

2 Stage-discharge relationships

Large flows usually are measured by development of and reference to a stage-discharge curve; this procedure has long been used by the U.S. Geological Survey. Such gauging stations are composed of a control structure located downstream of the location of measurement and some type of water level indicator which identifies the height of the water surface above a previously determined datum.

Location of the control structure so that reliable measurements of flow will be obtained at all river stages is particularly important. The water level may be continuously recorded by an automatic recorder located in a wet well or may be indicated directly on a staff gauge located at the bank of the river. Such stations must be calibrated by measurement of flow by velocity-area methods (current meter) at all expected stages of river flow.

3 Weirs

A weir may be defined as a dam or impediment to flow, over which the discharge conforms to an equation. The edge or surface over which the liquid flows is called the weir crest.

The sheet of liquid falling over the weir is called the nappe. The difference in elevation between the crest and the liquid surface at a specified location, usually a point upstream, is called the weir head. Head-discharge equations based on precise installation requirements have been developed for each type of weir. Weirs so installed are called standard weirs. Equations for non-standard installations or unusual types may be derived empirically.

Weirs are simple, reliable measurement devices and have been investigated extensively in controlled experiments. They are usually installed to obtain continuous or semi-continuous records of discharge. Limitations of weirs include difficulty during installation, potential siltation in the weir pond, and a relatively high head requirement, 0.4 - 2.0 feet. Frequent errors in weir installation include insufficient attention to standard installation requirements and failure to assure completely free discharge of the nappe.

r. Standard suppressed rectangular weir

This type of weir is essentially a dam placed across a channel. The height of the crest is so controlled that construction of the nappe in the vertical direction is fully developed. Since the ends of the weir are coincident with the sides of the channel lateral contraction is impossible. This weir requires a channel of rectangular cross section, other special installation conditions, and is rarely used in plant survey work. It is more commonly used to measure the discharge of small streams.

The standard equation for discharge of a suppressed rectangular weir (Francis equation) is:

$$Q = 3.33 LH^{3/2}$$

where

Q = discharge, cfs

L = length of the weir crest, feet

H = weir head, feet

The performance of this type of weir has been experimentally investigated more intensively than that of other weirs. At least six forms of the discharge equation are commonly employed. The standard suppressed weir is sometimes used when data must be unusually reliable.

b. Standard contracted rectangular weir

The crest of this type of weir is shaped like a rectangular notch. The sides and level edge of the crest are so removed from the sides and bottom of the channel that contraction of the nappe is fully developed in all directions. This weir is commonly used in both plant surveys and measurement of stream discharge.

The standard equation for discharge of a contracted rectangular weir (corrected Francis equation) is:

$$Q = 3.33 (L - 0.2H)H^{3/2}$$

where

Q = discharge, cfs

L = length of the level crest edge, feet

H = weir head, feet

0.2H = correction for end contractions as proposed by Francis

c. Cipolletti weir

The Cipolletti weir is similar to the contracted rectangular weir except that the sides of the weir notch are inclined outward at a slope of 1 horizontal to 4 vertical. Discharge through a Cipolletti weir occurs as though end contractions were absent and the standard equation does not include a corresponding factor for correction.



Figure 1. STANDARD CONTRACTED RECTANGULAR WEIR

The standard equation for discharge through a Cipolletti weir is

$$Q = 3.367 LH^{3/2}$$

where

Q = discharge, cfs

L = length of the level crest edge, feet

H = weir head, feet

The discharge of a Cipolletti weir exceeds that of a suppressed rectangular weir of equal crest length by approximately 1 percent.

d Triangular weirs

The crest of a triangular weir is shaped like a V-notch with sides equally inclined from the vertical. The central angle of the notch is normally 60 or 90 degrees. Since the triangular weir develops more head at a given discharge than does a rectangular shape, it is especially useful for measurement of small or varying flow. It is preferred for discharges less than 1 cfs, is as accurate as other shapes up to 10 cfs, and is commonly used in plant surveys.

The standard equation for discharge of a 90° triangular weir (Cone formula) is

$$Q = 2.49H^{2.48}$$

where

Q = discharge, cfs

H = weir head, feet

The head on a triangular weir is commonly measured at the crest itself, rather than at a point upstream. Crest height and head are measured to and from the point of the notch, respectively.

e Accuracy and installation requirements

Quotations of weir accuracy express the difference in performance between two purportedly identical weirs and do not include the effects of random error in measurement of head. Weirs installed according to the following specifications should measure discharge within $\pm 5\%$ of the values observed when the previously cited standard equations were developed.

- 1) The upstream face of the bulkhead and/or weir plate shall be smooth and in a vertical plane perpendicular to the axis of the channel.
- 2) The crest edge shall be level, shall have a square upstream corner, and shall not exceed 0.08 in. (2 mm) in thickness. If the weir plate is thicker than the prescribed crest thickness the downstream corner of the crest shall be relieved by a 45° chamfer.
- 3) The pressure under the nappe shall be atmospheric. The maximum water surface in the downstream channel shall be at least 0.2 ft. below the weir crest. Vents shall be provided at the ends of standard suppressed weirs to admit air to the space beneath the nappe.

- 4) The approach channel shall be straight and of uniform cross section for a distance above the weir of 15 to 20 times the maximum head, or shall be so baffled that a normal distribution of velocities exists in the flow approaching the crest and the water surface at the point of head measurement is free of disturbances. The cross-sectional area of the approach channel shall be at least 6 times the maximum area of the nappe at the crest.
- 5) The height of the crest above the bottom of the approach channel shall be at least twice, and preferably 3 times, the maximum head and not less than 1 foot. For the standard suppressed weir the crest height shall be 5 times the maximum head. The height of triangular weirs shall be measured from the channel bottom to the point of the notch.
- 6) There shall be a clearance of at least 3 times the maximum head between the sides of the channel and the intersection of the maximum water surface with the sides of the weir notch.
- 7) For standard rectangular suppressed, rectangular contracted, and Cipolletti weirs the maximum head shall not exceed 1/3 the length of the level crest edge.
- 8) The head on the weir shall be taken as the difference in elevation between the crest and the water surface at a point upstream a distance of 4 to 10 times the maximum head or a minimum of 6 feet. For triangular weirs the head shall be taken as the difference in elevation between the point of the notch and the water surface at the crest itself.

- 9) The head used to compute discharge shall be the mean of at least 10 separate measurements taken at equal intervals. The head range of the measuring device shall be 0.2 - 1.5 feet.

The capacities of weirs which conform to these specifications are indicated in Table 1.

4 Parshall flume

The Parshall flume is an open constricted channel in which the rate of flow is related to the upstream head or to the difference between upstream and downstream heads. It consists of an entrance section with converging vertical walls and level floor, a throat section with parallel walls and floor declining downstream, and an exit section with diverging walls and floor inclining downstream. Plan and sectional views are shown in Figure 2. Advantages of the Parshall flume include a low head requirement, dependable accuracy, large capacity range, and self cleaning capability. Its primary disadvantage is the high cost of fabrication; this cost may be avoided by use of a prefabricated flume. Use of prefabricated flumes during plant surveys is becoming increasingly popular.

a Standard equations

The dimensions of Parshall flumes are specified to insure agreement with standard equations. Table of dimensions are available from several sources^{3,4}. For flumes of 6 inch to 8 foot throat width the following standard equations have been developed.

- 1) 6 inch throat width

$$Q = 2.06 H_a^{1.58}$$

- 2) 9 inch throat width

$$Q = 3.07 H_a^{1.53}$$

TABLE 1 DISCHARGE OF STANDARD WEIRS

Crest Length (Feet)	Contracted Rectangular* Weir (discharge-cfs)		Suppressed Rectangular* Weir (discharge-cfs)		Cipolletti* Weir (discharge-cfs)		90° Triangular* Weir (discharge-cfs)	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1.0	.590	.286	.631	.298	.636	.301		
1.5	1.65	.435	1.77	.447	1.79	.452		
2.0	3.34	.584	3.65	.596	3.69	.608		
2.5	5.87	.732	6.30	.744	6.37	.753		
3.0	9.32	.881	10.0	.893	10.1	.903		
3.5	13.8	1.03	14.8	1.04	15.0	1.05		
4.0	19.1	1.18	20.4	1.19	20.6	1.20		
4.5	25.6	1.33	27.5	1.34	27.8	1.35		
5.0	28.8	1.48	30.6	1.49	30.9	1.51	6.55	.046
6.0	34.9	1.78	36.7	1.79	37.1	1.81		
7.0	41.0	2.07	42.8	2.08	43.3	2.11		
8.0	47.1	2.37	48.9	2.38	49.5	2.41		
9.0	53.2	2.67	55.0	2.68	55.7	2.71		
10.0	59.3	2.97	61.1	2.98	62.0	3.01		

* $H > 0.2$ ft, $H < 1.5$ ft, $H < 1/3 L$

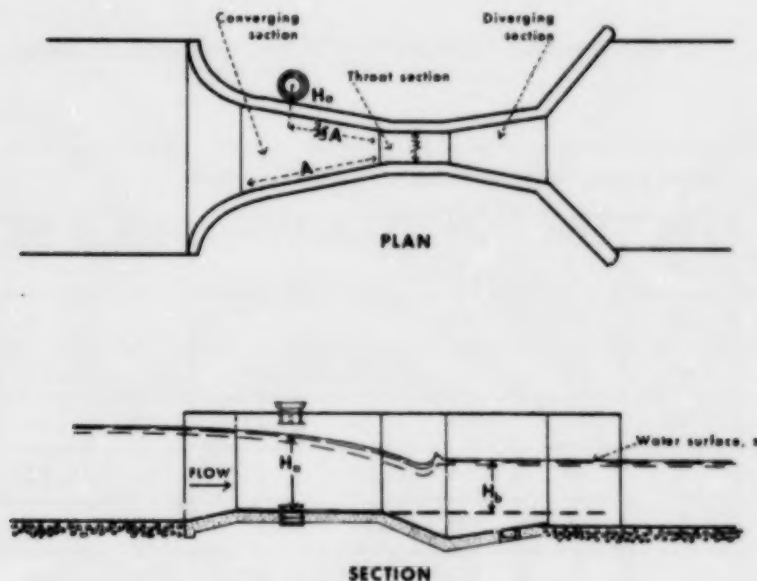


FIGURE 2 PARSHALL FLUME

3) 1 to 8 foot throat width

$$Q = 4WH_a^{1.522W^{0.026}}$$

where

Q = free-flow discharge, defined as that condition which exists when the elevation of the downstream water surface above the crest, H_b , does not exceed a prescribed percentage of the upstream depth above the crest, H_a . The prescribed percentage of submergence is 60 percent for 6 and 9 inch flumes and 70 percent for 1 to 8 foot flumes

W = throat width, feet

H_a = upstream head above the flume crest

b Head loss

The head required by a Parshall flume is greater than $(H - H_b)$ because H is measured at a point in the converging

section where the water surface has already begun to decline. Table 2 indicates the total head requirements of standard Parshall flumes. These losses should be added to the normal channel depth to determine the elevation of the water surface at the flume entrance. No head losses are indicated for discharge-throat width combinations for which H_b is less than 0.2 ft. or greater than $2/3$ the sidewall depth in the converging section.

c Accuracy and installation requirements

A Parshall flume will measure discharge within $\pm 5\%$ of the standard value if the following conditions are observed.

- 1) The dimensions of the flume shall conform to standard specifications.
- 2) The downstream head, H_b , shall not exceed the recommended percentage of the upstream head, H_a .

TABLE 2 HEAD LOSS IN STANDARD PARSHALL FLUMES
UNDER FREE DISCHARGE

Discharge (cfs)	Head Loss, Feet, in Flume of Indicated Width							
	1 foot	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
0.5	.08							
1.0	.14	.09	.06					
2.5	.26	.16	.12	.10	.08	.07	.06	.05
5.0	.42	.27	.20	.16	.13	.12	.10	.09
10.0	.70	.45	.34	.27	.22	.19	.17	.15
30.0			.70	.56	.47	.40	.35	.30
50.0					.68	.57	.49	.41

$$H_a \geq 0.2, \quad H_a \leq 2.0$$

- 3) The upstream head shall be measured in a stilling well connected to the flume by a pipe approximately 1 - 1/2 inches in diameter.
- 4) The flume shall be installed in a straight channel with the centerline of the flume parallel to the direction of flow.
- 5) The flume shall be so chosen, installed, or baffled that a normal distribution of velocities exists at the flume entrance.

5 Tracer materials

Techniques, materials, and instruments are presently being refined to permit accurate measurement of instantaneous or steady flow with several tracer materials. Measurements are made by one of two methods:

- a Continuous addition of tracer
- b Slug injection

With the first method, tracer is injected into a stream at a continuous and uniform rate; with the second a single dose of tracer material is added. Both methods depend on good transverse mixing and uniform dispersion throughout a stream. The concentration of tracer material is measured downstream from the point of addition. When continuous addition is employed, flow rates are calculated from the equation:

$$q \cdot C = (Q + q) c$$

in which q = rate of tracer addition to the stream at concentration, C , Q = the stream flow rate, and c = the resulting concentration of the stream flow combined with the tracer. For the slug injection method

$$Q = \frac{S}{\bar{c} \Delta t}$$

in which Q = the stream discharge, S = the quantity of tracer added, $\bar{c}$ = the weighted average concentration of tracer material during its passage past the sampling point, and Δt = the total time of the sampling period. Disadvantages of tracer methods include incomplete mixing, natural adsorption and interference, and high equipment costs.

6 Floats

Floats may be used to estimate the time of travel between two points a known distance apart. The velocity so obtained may be multiplied by 0.85 to give the average velocity in the vertical. Knowing the mean velocity and the area of the flowing stream, the discharge may be estimated. Floats should be employed only when other methods are impractical.

B Pipes and Conduits

1 Weirs and Parshall flumes

Weirs and Parshall flumes are commonly installed in manholes and junction boxes and at outfalls to measure flow in pipes. All conditions required for measurement of open channel flow must be observed.

2 Venturi meters

Venturi meters, Dall tubes, and similar type meters are useful in measuring flow in pipes.

In the Venturi tube, the rate of flow is expressed by:

$$Q = C \left(\frac{\pi}{4} \right) \frac{D_e^2 D_t^2}{\sqrt{D_e^4 - D_t^4}} \sqrt{2gh}$$

where: C = a coefficient (usually unity)

D_e = diameter of entrance

D_t = diameter of throat

- g = acceleration due to gravity
h = difference between pressure at entrance and at throat

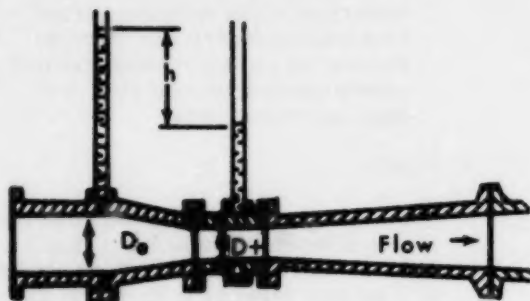


Fig. 2a - VENTURI METER

3 Pilot tubes

Pilot tubes are useful in measuring flow in closed conduits. It should be noted that their use in measuring waste flows is not recommended as waste solids may plug the tube openings and render erroneous readings.

4 Tracer materials

These methods are popular for measurement of pipe flow because they do not require installation of equipment or modification of the flow. These are especially convenient for measurement of exfiltration and infiltration.

5 Depth-slope

If the depth of the flowing stream and the slope of the sewer invert are known, the discharge may be computed by means of any one of several formulas.

a Manning formula

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

where

Q = discharge, cfs

- n = roughness coefficient
A = area of flow, sq. ft.
R = hydraulic radius, ft.
= area divided by wetted perimeter, ft.
S = slope, ft. per ft.

b Chezy formula

$$Q = CA \sqrt{RS}$$

where

- Q = discharge, cfs
C = friction coefficient
A = area of flow, sq. ft.
R = hydraulic radius, ft.
= area divided by wetted perimeter, ft.
S = slope, ft. per ft.

6 Open end pipe flow

The following methods can be employed when other more precise means are not practical. They can be employed, however, only when there is free discharge to the air.

a Coordinate method (Figures 3, 4, and 5)

Discharge may be computed by the following formula:

$$Q \text{ (gpm)} = \frac{1800 AX}{Y}$$

where

- A = cross sectional area of liquid in the pipe (sq. ft.)
X = distance between the end of the pipe and the vertical gauge in ft., measured parallel to the pipe.

Y = vertical distance from water surface at the end of the pipe to the intersection of the water surface with the vertical gauge, in ft.

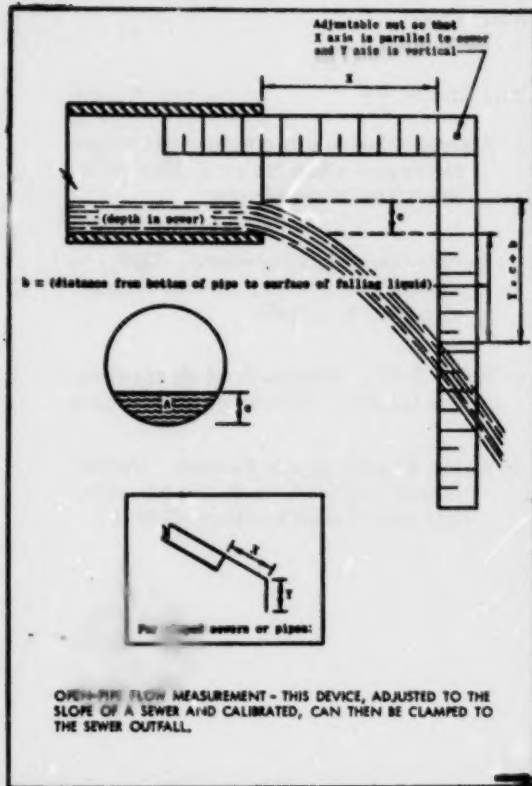


Figure 3

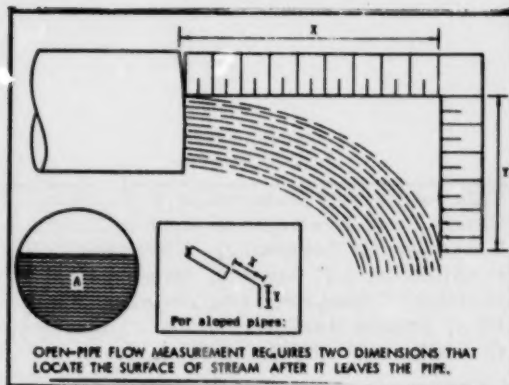


Figure 4

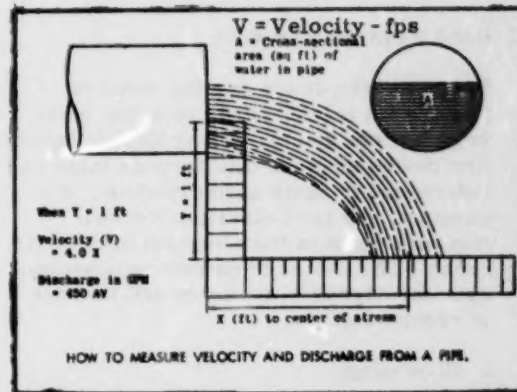


Figure 5

b California pipe flow method (Figure 6)

This method may be used only for horizontal pipes having free discharge. If the pipe is not horizontal, a connection must be made to one that is. The horizontal length must be not less than 6 times the diameter of the pipe. Discharge may be computed by the following formula:

$$Q \text{ (gpm)} = T \times W$$

$$\text{where } T = 3,900 \left(1 - \frac{a}{d}\right)^{1.88}$$

$$W = d^{2.48}$$

where a and d are measured in feet

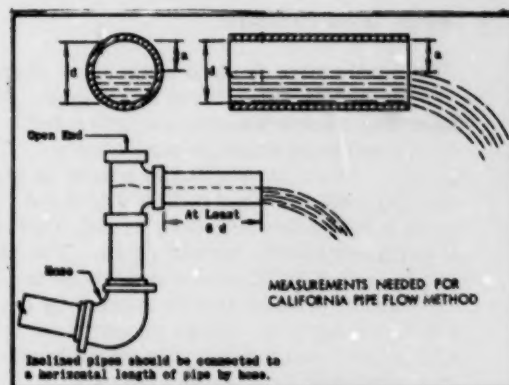


Figure 6

C Head Measuring Devices

Several of the above gauging methods require the measurement of water level in order that discharge may be determined. Any device used for this purpose must be referenced to some zero elevation. For example, the zero elevation for weir measurements is the elevation of the weir crest. The choice of method is dependent upon the degree of accuracy and the type of record desired.

1 Hook gauge

The hook gauge measures water elevation from a fixed point. The hook is dropped below the water surface and then raised until the point of the hook just breaks the surface. This method probably will give the most precise results when properly applied.

2 Staff gauge

The staff gauge is merely a graduated scale placed in the water so that elevation may be read directly.

3 Plumb line

This method involves measurement of the distance from a fixed reference point to the water surface, by dropping a plumb line until it just touches the water surface.

4 Water level recorder

This instrument is used when a continuous record of water level is desired. A float and counterweight are connected by a steel tape which passes over a pulley. The float should be placed in a stilling well. A change in water level causes the pulley to rotate which, through a gearing system, moves a pen. The pen traces water level on a chart which is attached to a drum that is rotated by a clock mechanism. When properly installed and maintained, the water level recorder will provide an accurate, continuous record.

ACKNOWLEDGMENT:

Certain portions of this outline contains training material from prior outlines by P. E. Langdon, A. E. Becher, and P. F. Atkins, Jr.

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SEDIMENTATION BASINS IN WASTEWATER TREATMENT

I FUNCTION AND TYPE OF SEDIMENTATION BASIN

A Function

- 1 Grit removal
- 2 Primary sedimentation
 - a Alone or in advance of other processes
 - b With or without chemicals
- 3 Secondary sedimentation - following biological treatment
- 4 Sludge thickening

B Shape and Type

- 1 Horizontal flow - mechanical sludge removal
 - a Rectangular
 - b Circular
 - 1) Center feed
 - 2) Peripheral feed
 - c Imhoff tank
 - d Septic tank
- 2 Vertical flow
- 3 Tube settler¹⁰

II TYPICAL DESIGN CRITERIA

A Overflow Rates

Most State Standards specify maximum overflow rates in primary tanks of from 600 to 1,000 gpd per square feet with smaller plants using the lower rates. In secondary clarifiers, maximum overflow rates of 800-1,000 gpd per square feet are commonly specified.

B Detention Time

Some states set limits on both maximum overflow rate and minimum detention time. A figure of 2 hours' detention for primary

tanks is common although shorter times are permitted for primary tanks ahead of activated sludge. For secondary tanks, 2 hours' detention is a common specification. The Ten State Standards do not specify detention times, but do set a minimum depth of 7 feet on primary and 8 feet on secondary tanks, which is tantamount for setting a minimum detention time, since

$$T = \frac{180 D}{V_o}$$

where T = Detention time (hours)
 D = Tank depth (ft)
 V_o = Overflow rate (gpd per sq. ft.)

Thus, a tank with an overflow rate of 600 gpd per sq. ft. and a depth of 7 ft. has a detention time of 2.1 hours.

C Weir Loading

A number of states specify weir loading rates of the order of 10,000-15,000 gpd per lin. ft. of effluent weir.

D Other Criteria

Some states specify minimum distances from inlet to outlet, scum baffles are commonly required, and, as a rule, some requirement is set regarding even distribution of flow and dissipation of kinetic energy at the inlet.

III THEORY OF SEDIMENTATION

A Allen Hazen¹

Hazen's paper published in the Transactions of the American Society of Civil Engineers in 1904 outlined the commonly accepted theory of settling of discrete particles in quiescent basins and discussed the effect of departures from ideal conditions. According to this theory sedimentation efficiency is a function of overflow rate and independent of depth.

B Thomas R. Camp²

Camp's paper on the Transactions of the American Society of Civil Engineers in 1946 elaborated on Hazen's theory, outlined the use of settling tube tests to

determine the properties of suspensions, discussed settling of flocculent suspensions, scour of deposited materials, the effects of short circuiting and turbulence. He recommends the use of long shallow tanks for sedimentation with the depth being limited only by considerations of avoiding scouring velocities and the need for sludge removal equipment. This paper with the discussions that accompany it is probably the best single paper on the subject of sedimentation basin design.

Quote from the discussion of the paper.

E. Sherman Chase: "... the design of practicable settling tanks will continue to be based upon judgment, experience, and common sense seasoned with a moderate amount of theoretical computations used as aids to judgment."

T. R. Camp: "This attitude has undoubtedly been that of most of the designers of tanks The moderate amount of theoretical computations which Mr. Chase suggests for seasoning the judgment has unfortunately been so moderate that it has been almost completely absent. Design has consisted almost wholly of conformity to previous practice in size and shape with little regard for the principles involved or for the nature and settling characteristics of the particles to be settled."

C E. B. Fitch³

Fitch, in *Sewage and Industrial Wastes* in 1957, makes the point that in dealing with flocculent suspensions a deep tank provides better opportunity for particle growth than a shallow one and hence that detention time cannot be discarded as a criterion in settling tank design. He also points out that hydraulic efficiency or absence of short circuiting is not necessarily important to good tank performance.

D Ronald T. McLaughlin⁴

McLaughlin, in the *Hydraulics Division Journal of ASCE* in December, 1959, points out how the properties of the suspension determine whether detention time, overflow rate, or both may be important to efficient sedimentation.

IV COMPLICATING FACTORS

A Flocculation

Most of the suspensions dealt with in wastewater treatment do flocculate.

Exception - Grit. Extreme case - Activated sludge. Intermediate - Raw sewage.

B Flow Variations

The typical wastewater treatment plant is subject to wide variations in flow. It is virtually impossible to design a sedimentation tank that will behave in the same way hydraulically with flow varying by as much as a factor of 5-10 from maximum to minimum.

C Solids Removal

Sludge and scum removal mechanisms perturb somewhat the settling of suspended matter. It is necessary to consider a portion of the tank volume ineffective because of the operation of these mechanisms.

D Solids Concentration

It is commonly found that removal efficiency of sedimentation basins is higher when dealing with concentrated suspensions than when influent concentrations of suspended solids are low. It is not usually known why this is so. In some cases, it may be due to differences in the size distribution of the suspension. Many sewers act as crude settling basins which are periodically flushed out. At times of flush-out, this relatively coarse material reaches the treatment plant. High concentrations of suspended solids make for more effective flocculation as well. This accelerates settling.

E Inlet Design

A portion of any tank is ineffective for sedimentation because of need to dissipate influent kinetic energy and distribute flow evenly. In long tanks, the ineffective fraction of the tank is smaller than in short tanks. Flow variations and the necessity of avoiding small openings usually prevent the introduction of a controlling head loss to get even flow distribution.

F Density Currents

Virtually all tanks are affected by density currents. Activated sludge secondary tanks always have them, and most primary tanks have them from time to time. Anderson⁵ has developed a design of secondary tank with an annular weir to improve efficiency of circular tanks. Gould in New York adopted another way of coping with density currents in rectangular secondary tanks. He places the sludge hopper near the effluent end of the tank instead of at the influent end.

G Resuspension of Deposited Solids

This limits acceptable horizontal velocities. Camp, using Shields formula, estimates that velocities as high as 7-8 fpm are acceptable. In primary tanks at Hyperion, there was evidence of resuspension when velocities exceeded about 4 fpm.⁶ The presence of density currents can affect resuspension markedly. Burgess and his colleagues⁷ studied flow patterns in the primary tanks of the Northern Outfall Works of the London County Council and found a very marked density current.

	Rectangular Tanks		Circular Tanks	
	Mean	Std. Dev.	Mean	Std. Dev.
Length or diameter ft.	118	53	86	32
Depth, ft.	10.9	1.85	10.5	1.96
Length/width	3.77	1.40	-	-
Detention time, hrs.	2.53	1.44	2.65	1.12
Overflow rate, gpd/ft ²	997	535	856	360
Influent suspended solids, mg/l	227	105	234	71
Effluent suspended solids, mg/l	106	60	89	33
% removal suspended solids	52.6	15.5	60.8	11

V PLANT PERFORMANCE

Comparatively few extensive studies of plant performance to guide engineer in design.

A NRC Study of Military Treatment Plants⁸

Studied 20 months of operating data from 18 primary plants. Mean BOD removal for the 18 plants ranged from 10 per cent to 61 per cent. Not only was there large variation between plants but also large variation in a given plant from one period to the next. Average detention period for the 18 plants was 3.77 hours, average overflow rate was 506 gpd per sq. ft. Median displacement velocity was 0.4 fpm. Detention period correlated more closely with removal efficiency than did overflow rate. There was no significant difference between circular and rectangular tanks, other things being equal. The following formula was used to fit the data for 10 plants where there was no recirculation to the primary tanks:

$$\text{Fractional Removal of Suspended Solids} = \frac{0.67 T}{1 + 0.94 T}$$

B Data in ASCE - WPCF Manual of Sewage Treatment Plant Design

An analysis of data from 32 plants with rectangular primary tanks and 25 plants with circular primary tanks has been made. The following table shows data on size, loading, and performance at these plants:

Multiple correlation analysis were made on these data, using per cent removal of suspended solids as the dependent variable and various parameters as independent variables. There was little to choose between detention time and overflow rate as variables in predicting performance. There was no indication of marked superiority of one shape of tank over the other. As in the NRC study, there is a wide scatter of points about the fitted curve.

Equations fitted to the data were

Circular Tanks

$$\text{Fraction S. S. removed} = \frac{2.5 T}{1 + 3.8 T} \text{ and}$$

$$\text{Fraction S. S. removed} = \frac{2,940}{4,100 + V_o}$$

Rectangular Tanks

$$\text{Fraction S. S. removed} = \frac{.49 T}{1 + .55 T} \text{ and}$$

$$\text{Fraction S. S. removed} = \frac{1,350}{1,920 + V_o}$$

where T is detention time in hours

V_o is overflow rate in gallons per day per square foot.

C Secondary Clarifiers at Chicago Activated Sludge Plants

A secondary clarifier in an activated sludge plant is called upon to do a vastly more efficient job of solids separation than one expects of primary tanks. The influent contains thousands of mg/l of suspended solids and the effluent is expected to contain only tens of mg/l of suspended solids. Thus, we look for 99 percent or more removal of suspended solids. To achieve this, it is essential that the activated sludge be well flocculated and that only a small amount of the suspended solids be in small particles.

An analysis of two years operating data from five of the operating batteries at the three large Chicago activated sludge plants has been made to get some insight into the importance of various operating variables in determining plant performance.

The analysis shows clearly the superiority of the Anderson design with annular weirs over the older design with peripheral weirs. Overflow rate was not an important determinant of effluent suspended solids, although the five batteries had an average overflow rate of over 1,200 gpd per sq. ft. Temperature had a significant effect on clarifier efficiency. An organic loading parameter, pounds of BOD per day per pound of mixed liquor suspended solids, had a greater effect than either of the other variables.

The plants had average loadings of .19 pounds of BOD per day per pound of mixed liquor suspended solids with a range of monthly values of this parameter from .09 to .51. Effluent suspended solids for all of the plant units were 15 mg/l, with monthly averages ranging from 5 to 96 mg/l.

Sludge volume index was not a significant index of performance. It should be pointed out, however, that sludge volume indices were quite low, averaging 75 and varying from 46 to 139.

This analysis indicates that with well flocculated activated sludges excellent solids separation can usually be obtained at overflow rates considerably higher than those usually recommended. However, from time to time one must expect the system to get out of control and suspended solids carry-over in the effluent to occur.

VI CONCLUSION

In spite of the fact that theoretical considerations indicate that overflow rate should be a more significant parameter than detention time in design of sedimentation basins, plant performance data do not support the superiority of one design parameter over the other in plants with conventional depths.

Sedimentation basins generally show rather erratic performance in time. This is probably due at least in part to the inherent instability of flow patterns in basins with horizontal velocities low enough to prevent resuspension of deposited material. Flow fluctuations, changes in waste composition, wind, and solar radiation are other perturbing influences.

Although circular horizontal flow tanks are notoriously prone to short circuiting their performance in solids removal appears to be as good as that of rectangular tanks similarly loaded. The lower maintenance costs of sludge removal mechanisms in circular tanks is probably the most important factor in choosing between circular and rectangular tanks.

There is no rational basis for the relatively low overflow rates set by most of the state design standards. At small plants where the marginal cost of providing additional tank capacity is proportionately much less than in larger plants, there is probably not much reason to skimp on basin size, but in larger plants there may be significant economy in using higher rates. Overflow rates much higher than the conventional 600-1,000 gpd per sq. ft. are used in many plants with good efficiency.

There is little reason for maintaining low weir loading rates in primary tanks. In secondary tanks following activated sludge low weir loadings are important.

The tube settlers¹⁰ that have been introduced recently have not as yet been tested enough for any conclusion to be reached as to their general usefulness in wastewater treatment. This development will be watched with interest.

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This outline was prepared by R. L. Woodward, Camp, Dresser and McKee Engineers, Boston, Massachusetts.

SEDIMENTATION TANK EQUIPMENT

I INTRODUCTION

The primary objectives of sedimentation equipment is the removal of settleable solids and floatable scum.

- A Primary sedimentation objectives are to remove concentrated sludge without troublesome septicity.
- B Secondary sedimentation requires prompt return of fresh solids with concentration as a secondary requirement.
- C Basin, sludge collection, scum removal, drive mechanisms and available equipment will be discussed relative to A and B.

II SLUDGE COLLECTION EQUIPMENT

A General

Much equipment available, more similarities than differences. Three basic shapes of tanks: circular, rectangular, square.

B Circular Clarifier - Center Inlet

1 General

Most common flow pattern. Sewage enters center well, either through side of tank, or underneath and up. Sewage flows downward, then radially, over a peripheral weir.

2 Manufacturers

Infilco, Carter, Eimco, Yeomans, Dorr, Rex, Walker, Link-Belt, Hardinge.

3 Beam Supported Type

Scraper blades mounted on truss revolve about center shaft scraping sludge to central well. Supported from beams spanning tank. Full weight and torque carried by beams. For small tanks, usually 50 ft. in diameter or less. Motor driven at center. Skimmer connected to same shaft.

4 Center Column Type

For larger tanks up to 200 ft. diameter. Scraping mechanism similar to beam supported type. Scraper assembly

suspended from a turntable carried by a central column. Rotated by means of motor driven gears mounted on a fixed bridge. Sewage enters up through hollow column, then flows radially.

5 Peripheral Drive

Center column. Rotating bridge drives scraping assembly. Driven peripherally by motor driven wheels on wall of tank. Not too common in New England. Snow and ice problems. Manufacturers: Infilco, Eimco, Walker.

6 Suction Type

For secondary sludge, mainly activated sludge. Suction pipes mounted on scraper truss. Suction created by hydrostatic head. Eimco, Dorr, Rex, Walker.

7 Radial Chain Scraper Type

Not common. Radially mounted endless chain type, scraping towards center while rotating. Peripheral drive. Link-Belt.

C Circular Clarifier - Peripheral Inlet

Sewage enters tangentially into a peripheral race. Skirt extends to 18" from floor. Sewage flows under skirt, then upward and over central weir. Scum, in theory, remains in raceway. Sludge removal equipment bridge supported. Lakeside, Yeomans, Rex.

D Rectangular Tanks

1 General

Sewage enters at end, is baffled, flows longitudinally to other end, out over weir.

2 Standard Chain Type

Oldest type. Chain and sprocket type. Flights attached to chains run on rails. Scrape sludge to hopper at inlet end. Cross collectors provided in hoppers of large tanks. Rex, Walker, Link-Belt, Yeomans, Jeffrey.

3 Moveable Bridge Type

Bridge spans tank width, running on rails. Rakes hung from bridge contact floor and move sludge to end of tank.

a Traction drive

Motor mounted on bridge. Electricity supplied by reel and cable. Hardinge, Link-Belt, Rex, Komline-Sanderson.

b Cable drive

Stationary drive at end of tank. Pulls cables attached to moving bridge. Dorr.

E Square Tanks

Flow can be center inlet, peripheral weir; or straight across flow. Mechanism similar to circular tanks except for extension arms which reach into corners, and scrape sludge back to normal radius of scraper. Not common. Dorr, Walker, Link-Belt, Rex.

III SCUM REMOVAL MECHANISMS

A Circular Tanks (Primary)

Skimming device rotates on center shaft. Details vary, but all types force scum towards periphery where it is deposited in scum box. Flows or is flushed to scum pit. Peripheral feed: Scum in raceway flows to a tilting skimming pipe. Incomplete removal. Scum still rises in main settling tank.

B Rectangular Tanks (Primary)

Return flights travel the surface forcing scum to end. Usually picked up in a revolving skimming pipe. Other types.

C Secondary Tanks

It is not standard practice to install scum removal mechanisms on secondary tanks. However, observations in Northeast Region leads us to believe that they are needed. We have been thinking of making this a firm requirement.

IV DRIVE MECHANISMS

Slow speed of rotation requires a large speed reduction ratio. Various types of reducers and gearing arrangements used, depending upon diameter (or length) of tank and sludge load.

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PRACTICAL ASPECTS OF OXYGEN TRANSFER

I INTRODUCTION

A The Need

An adequate supply of dissolved oxygen, which is normally transferred by mechanical means, is required by aerobic biological oxidation process such as activated sludge and aerated lagoons.

B Transfer Techniques

Many different oxygen transfer devices are marketed. All of them transfer oxygen from air by the generation of air-water interfaces.

The potential use of a pure oxygen atmosphere and the generation of oxygen-water interfaces may be implemented in the future to meet higher rates of oxygen demand.

C Objective

The objective in any oxygen transfer system is to adequately provide the oxygen requirements and to do so as economically as is possible.

II OXYGEN TRANSFER THEORY

A Oxygen transfer across an air-water interface follows a first order relationship which can be expressed as:

$$N = K_L (C_s - C_L)$$

which is based on the two film theory and the assumption that most of the resistance is on the liquid side. N is the mass transferred per unit of area per unit of time or the rate of diffusion. K_L is the overall liquid mass transfer coefficient, C_s is the oxygen concentration at the interface and C_L is oxygen concentration in the body of the liquid.

B The area through which mass transfer is taking place usually is not known; hence, area is combined with the mass transfer coefficient to give a composite coefficient $K_L a$

$$N_a = K_L a (C_s - C_L)$$

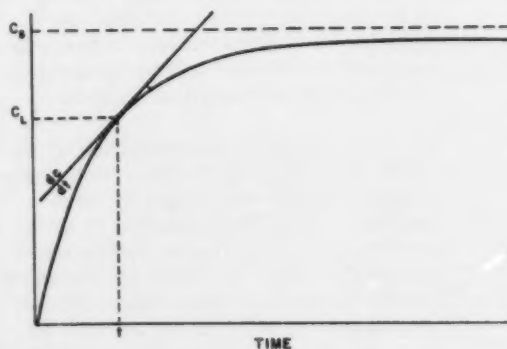
where N_a is mass transferred per unit of time per unit of driving force.

C Considering oxygen transfer into a given body of water as a special case, mass transfer can be expressed as:

$$\frac{dC}{dt} = K_L a (C_s - C_L)$$

The value of $K_L a$ in concentration terms applies only to the particular aeration system in which the measurements are made. The relationship is shown graphically in Figure 1.

Figure 1
OXYGEN TRANSFER RELATIONSHIP
CONCENTRATION BASIS



III MEASUREMENTS OF OXYGEN TRANSFER

A Non-Steady State Systems

Interpretation of oxygen transfer into water where oxygen consumption is not involved utilizes the integrated form of the differential equation for the calculation of the oxygen transfer coefficient

$$K_L a = \frac{\ln \frac{C_S - C_{L1}}{C_S - C_{L2}}}{t_2 - t_1}$$

Practical evaluation of non-steady state oxygen transfer must recognize the following factors.

- 1 Determinations of oxygen concentration are usually accomplished by the Winkler titration procedure or with dissolved oxygen probes. Dissolved oxygen probes are convenient and suitably accurate, but the response time of probes is significant and must be accounted for in the interpretation of results.

If samples can be collected rapidly enough (such as by the use of pumps), the problem of response is minimized by utilizing the Winkler determination. There are interferences with the Winkler such as high results due to cobaltous ion concentrations (used as catalyst) of greater than about 0.1 mg/l. Also, in high shear systems, colloidal dispersion of air (not visible to the naked eye) can occur and will be titrated incorrectly as dissolved oxygen.

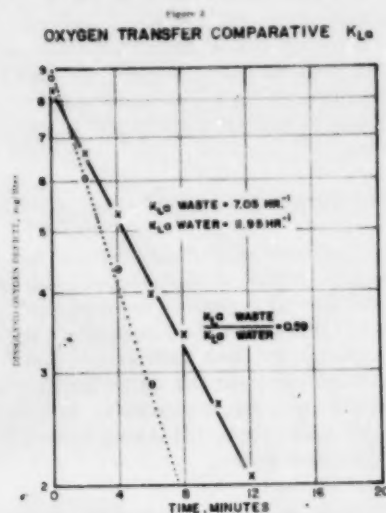
- 2 Deoxygenation is accomplished by the addition of sodium sulfite which reacts with the dissolved oxygen to form sulfate. Cobaltous chloride is added as a catalyst. The sodium sulfite must be in solution when added to the aeration basin to insure that the apparent rate of oxygen transfer is not interfered with by the rate of solution of the sulfite.

The cobaltous ion must be added in catalytic concentrations. If water in the system contains materials which complex cobaltous ions, enough cobaltous chloride must be added to satisfy the complexation reaction and to provide a catalytic concentration. The cobaltous ion may interfere with the determination of oxygen by the Winkler procedure, but it does not interfere with dissolved oxygen probes.

- 3 In very large aeration basins, dispersion of the sodium sulfite throughout the basin is a problem. Care must be taken to achieve thorough dispersion. Usually, introduction of the sulfite solution into the suction flow to the aeration equipment is adequate.
- 4 Non-steady state transfer becomes very difficult when more than one entrainment aerator exists in a basin because of the problem of uniform dispersion.
- 5 The proper concentration of dissolved oxygen at saturation must be used. If air-water interfaces are generated under a head of water, the dissolved oxygen concentration at the mean pressure should be utilized. When entrainment aerators are involved, saturation values at atmospheric pressure are usually adequate. However, in smaller basins, bubbles may be mixed into the basin volume rather than escaping at the surface. Under this condition, the mean saturation value is determined by observations of the actual saturation value in the basin.

Non-steady state data from a small-scaled pilot plant used to evaluate the aerated lagoon process are shown in Figure 2. Tap water was introduced into the aeration basin and oxygen transfer data were collected. The basin was then filled with treated wastewater and oxygen transfer data

were collected under identical conditions. The result showed that the same transfer effort resulted in a transfer rate to the wastewater equal to 59 percent of the rate to tap water.



B Steady State Systems

For any system under aeration, the instantaneous rate of oxygen transfer is directly proportional to the driving force $C_S - C_L$. Therefore, if an aeration effort is applied to a system which has a demand for oxygen, an equilibrium is established when the driving force is reduced to a point where the rates of oxygen transfer and oxygen demand are equal.

$$\frac{dc}{dt} = K_L a (C_S - C_L) = r$$

where r is the rate of oxygen consumption. Data determined at equilibrium may be utilized to determine the coefficient of oxygen transfer.

$$K_L a = \frac{r}{C_S - C_L}$$

The steady state technique must be utilized for the examination of oxygen transfer into the activated sludge process because of the following reasons.

- 1 Raw wastewater, which might be used in non-steady state evaluation, may contain surface active agents which will be degraded in the biological system. In other cases, surface active agents may be synthesized during biological degradation. Therefore, the raw wastewater cannot be assumed to be a representative of water in the mixed liquor.
- 2 The treated effluent is not a representative system because it does not contain the activated sludge solids.
- 3 The actual mixed liquor is the representative system because it contains the factors of suspended solids and surface active materials in the proper concentrations. Additionally, carbon dioxide evolution from the system is in progress. Carbon dioxide evolution in highly active systems can reduce the rate of oxygen transfer by as much as 25 percent and, therefore, is a significant factor.

Oxygen transfer evaluation under steady state conditions should consider the following factors.

- 1 Oxygen uptake rate in the mixed liquor is established through a dynamic ratio of food-to-microorganisms. If a mixed liquor sample is removed from the system, the food supply is shut off, and the oxygen uptake rate may decrease significantly within a matter of seconds.

In small systems, oxygen uptake rate should be determined by stopping aeration, continuing feeding, and providing gentle agitation to suspend the activated sludge solids while the rate of decrease in dissolved oxygen is observed.

In large systems, the mixed liquor should be pumped through a container which contains a dissolved oxygen probe (Figure 3) until an essentially constant dissolved oxygen concentration is observed. The pump is then stopped and oxygen uptake rate is observed

immediately thereafter. The solids must not be permitted to settle or additional air input supplied during test.

- 2 In large aeration basins, the value of C_L cannot be the same at all locations and must decrease from the time that mixed liquor leaves the aeration zone until it returns. The mean value of C_L should be determined.
- 3 Dissolved oxygen values at saturation involve the same problems as those which were noted for non-steady state oxygen transfer evaluation. The same considerations must be applied.

IV FUNDAMENTAL DATA IN OXYGEN TRANSFER SPECIFICATIONS

Based on the preceding discussion, it is relatively apparent that a manufacturer cannot provide oxygen transfer equipment on the basis of a stated dissolved oxygen requirement. It is necessary to provide him with additional information about oxygen transfer resistances, saturation values, minimum allowable concentration of dissolved oxygen and range of operating temperatures.

1 Oxygen transfer resistances (α value)

Information about resistances to oxygen transfer are obtained by the engineer by determining $K_L a$ values for the activated sludge system (steady state data) and tap water (non-steady state data) under identical conditions in bench-scaled equipment. The ratio of $K_L a$ for wastewater to $K_L a$ for tap is referred to as the alpha value (α).

2 Saturation values (β values)

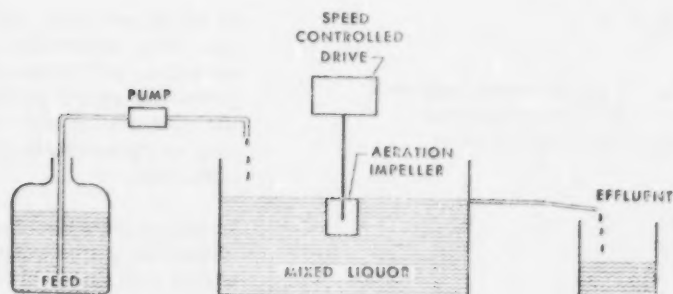
The engineer observes whether or not the concentration of dissolved oxygen in the mixed liquor at saturation (determined on a supernatant sample) is equal to or less than saturation in distilled water at the same temperature. Saturation in the wastewater is defined as the factor beta (β) times saturation in distilled water.

3 Minimum allowable dissolved oxygen concentration

The mixed liquor of the activated sludge process must remain aerobic, but the dissolved oxygen concentration in the

Figure 3

OXYGEN TRANSFER DETERMINATION
BENCH-SCALED APPARATUS FOR STEADY-STATE DATA



$$K_L a = \frac{r}{C_S - C_L}$$

process should be allowed to go as low as possible to take advantage of the maximum driving force. The minimum allowable dissolved oxygen concentration is usually about 0.5 mg/l, but in certain cases higher values may be required.

4 Range of operating temperatures

As the operating temperature increases the driving force decreases because of the decreased solubility of dissolved oxygen. Normally, the limiting oxygen transfer conditions are found at elevated temperatures.

If very cold operating conditions are anticipated (in the order of zero to 5°C) limiting oxygen transfer can be encountered because the oxygen transfer coefficient varies as a function of temperature.

$$K_L a_T = K_L a_{20} \cdot 1.024^{20-T}$$

5 Summary of fundamental oxygen transfer data

a Oxygen transfer requirement

b α value

c β value

d Minimum allowable dissolved oxygen concentration

e Range of operating temperatures

6 Additional considerations should take into account basin configuration and the numbers of aeration units as related to adequate mixing of basin contents as well as dispersion of dissolved oxygen.

In large systems where the demand for oxygen is variable, economy through power savings can be realized if the oxygen transfer capacity is paced in proportion to the oxygen demand. Dissolved oxygen analyzers, logic units and interfacing equipment are used to control the oxygen transfer equipment.

This outline was prepared by Vernon T. Stack, Director of Research and Development, Weston and Stack, Inc., Newtown Square, Pennsylvania.

THE PROCESS EQUIPMENT FOR SLUDGE HANDLING, DIGESTION AND DISPOSAL

I INTRODUCTION

A The handling, digestion, and ultimate disposal of sludge is probably the most difficult and perplexing problem in the field of sewage treatment. A major portion of the cost for sewage treatment, both for initial plant construction and for operation, is contributable to this process. In spite of this large outlay for many plants, the disposal problem in many plants is not being solved either for the immediate needs or that in the foreseeable future.

B The history of sewage treatment includes the development and gradual evolution of process equipment. There are a number of manufacturers marketing various types of equipment and promoting different processes for the handling of waste sludge. In the future we are bound to see even new approaches advancing beyond that which we know today due to the acute problem of sludge disposal.

C The handling of sludge should be considered as a system and equipment selected to provide the efficiency necessary for good operation with minimum maintenance and operating attendance. Flexibility of operation is required due to the large variations in waste characteristics and loadings. (Figure 1)

II SLUDGE PREPARATION

A Concentration

One of the most important considerations in the withdrawal of sludge from clarification basins is the concentration of the sludge. It is imperative that provision be made for withdrawing the thickest possible sludge, as much of the sludge handling equipment, whether it be digestion, incineration, etc., is based on the volume of sludge handled not the pounds of dry solids.

SLUDGE PREPARATION, HANDLING AND DISPOSAL OPERATIONS

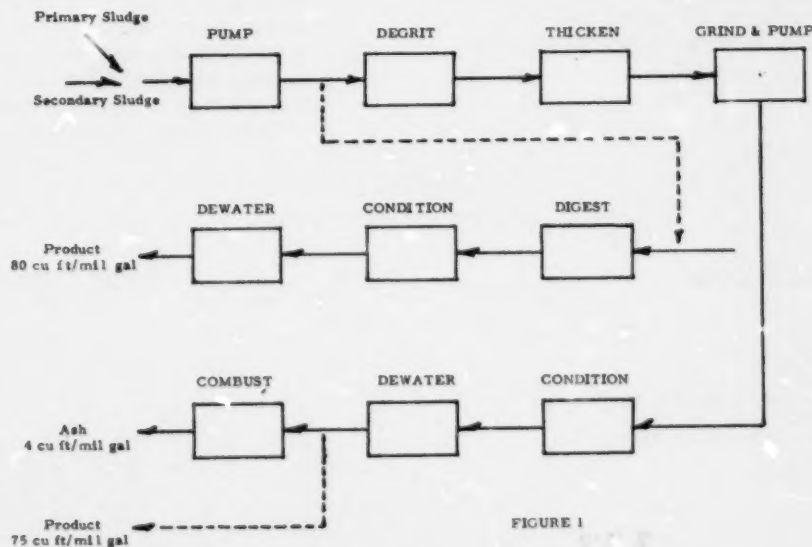


FIGURE 1

- 1 Control of the underflow consistency of sludge may be provided by either manual or automatic supervision or the addition of additional unit operations:
 - a Observation wells with telescopic valves are employed to allow visual observation of the sludge as it is withdrawn. However, this requires operation attendance and flow varies greatly depending on solids concentration.
 - b Sight glasses have been installed in sludge withdrawal lines for visual observation. This approach is generally not satisfactory.
 - c Timers may be programmed to operate sludge pumps at predetermined times and operating periods.
 - d Density meters mounted in the sludge line give a direct readout and also can be provided with electrical means for pumping sludge having only the desired concentration.
- 2 Gravity thickening in circular tanks using a modified clarifier raking mechanism is widely used to minimize sludge volume. The primary and secondary waste sludge is diluted to 3500-5000 milligrams per liter (mg/l) with final effluent to maintain an aerobic state in the thickener liquor. The design basis for thickeners is as follows: (Figure 2)

The underflow density is maintained by controlled pumping from the sludge blanket. The sludge blanket contains about 0.75 to 1.5 days of storage. The solids concentrations noted above are approximately the maximum concentrations that should be fed to digesters due to ammonia toxicity.

- 3 Flotation thickeners are often used for concentrating waste activated sludge and are preferable to gravity units when there is no primary sludge. The sludge is floated by dispersing minute air bubbles into the waste sludge under pressure. The release of pressure enlarges the bubbles and they float the attached particles to the surface where they are skimmed.

Flotation units are loaded to 20 lbs/sq ft/day without chemical addition and 50 lbs/sq ft/day with the addition of polyelectrolytes. Polymer cost is generally \$3 to \$6 per ton of dry solids and sludge concentration is 4-6% total solids (TS). Solids recovery is 80-90% of the feed. (Figure 3)
- 4 Centrifugal thickening of waste sludges, particularly activated sludge, is being revived. The recycle disc nozzle centrifuge can thicken waste activated sludge to 6-8% TS without requiring chemicals while recovering over 90% of the feed solids. Power requirements are 0.3-0.5 horsepower per gallons per minute (hp/gpm) of feed. Capacity of the units range up to 400 gallons per minute (gpm). (Figure 4)

TABLE I
GRAVITY THICKENING

Type of Sludge	Loadings	Sludge Underflow % TS
	Pounds Per Square Foot Per Day (lbs/sq ft/day)	
Primary	20	9 - 12
Primary + Biofilter	12	7 - 8
Primary + Activated	8	5 - 6
Activated	4	2.5 - 3.5

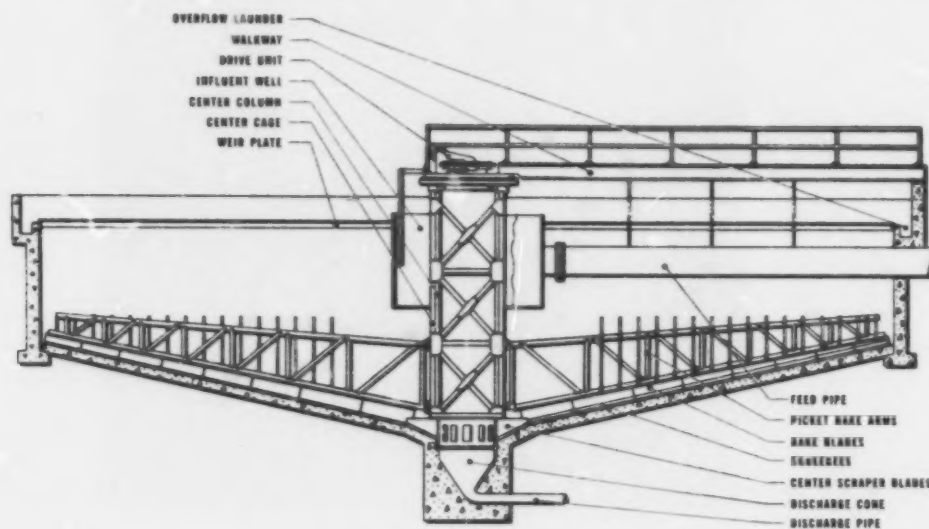


FIGURE 2. Dorr-Oliver Densludge Thickener

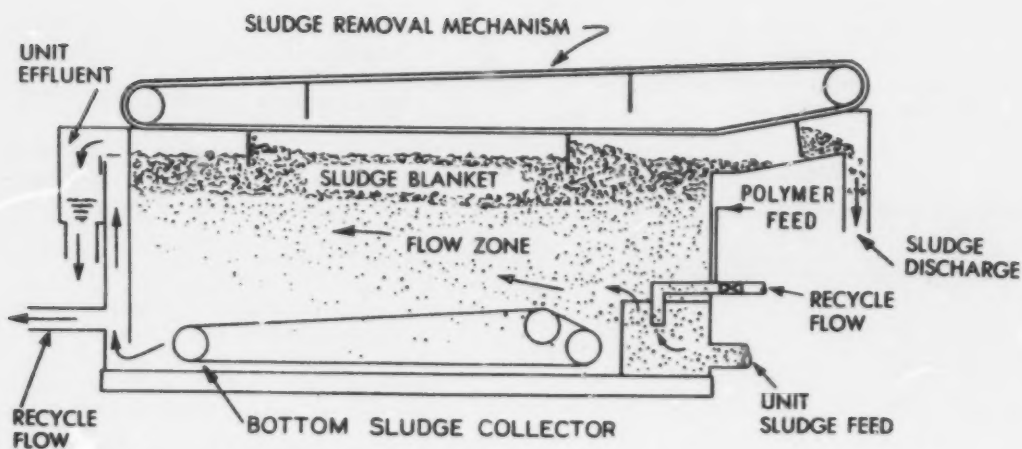


FIGURE 3. Komline-Sanderson H-R Type Flotation Unit Internal Flow Diagram

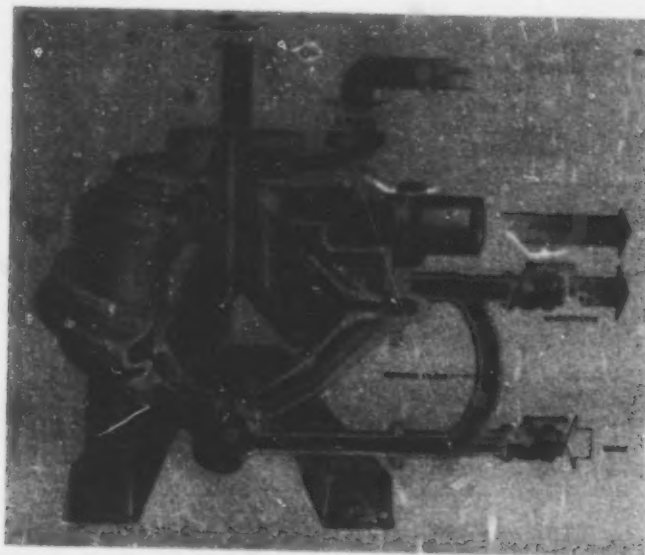


FIGURE 4. Merco Centrifuge

B Sludge Degritting

In conjunction with gravity thickening, hydrocyclone degritting of the primary sludge at a concentration of less than 1% TS is often practiced. The efficiency is much higher than conventional grit chambers (+65 mesh) and as much as three times the grit quantity is removed. Since the degritting is practiced on a constant primary sludge underflow, efficiency is not affected by peak or storm flows. The removal efficiency for a 12 inch (in) hydrocyclone is as follows: (Figure 5)

TABLE II
DORRCLONE DEGRITTING EFFICIENCY

Mesh Range	Grit Removal - %
+ 65	100
- 65 + 100	100
-100 + 150	95
-150 + 200	70

C Sludge Grinding

In spite of preliminary screening procedures employed, operating experience indicates

that large particles cause significant down-time and operator attendance at most plants. Gaining acceptance is the use of in-line sludge grinding which produces a -3/8 in particle. Unit capacities range up to 400 gpm on dilute or thickened sludge.

1 The "Sulzer Disintegrator" and the recently developed "Moyno Mazorator" will grind up to 200 gpm of thickened sludge with 10-15 horsepower (hp). Grinding is accomplished in the manner of a meat grinder with perforated plate and high speed cutter blades. (Figure 6)

2 The "Gorator" combines grinding and pumping in a single unit. It is commonly used to pump sludge to a hydrocyclone.

D Sludge Pumping

The sludge pumps are selected depending on the application and operating characteristics. Selection should consider solids particle size, suction and head requirements, and high viscosity of thickened sludges.

1 Dilute sludges may be effectively handled by centrifugal pumps which allow for the passage of large particles. Suction should be submerged.



FIGURE 5. Dorrcone Degritting

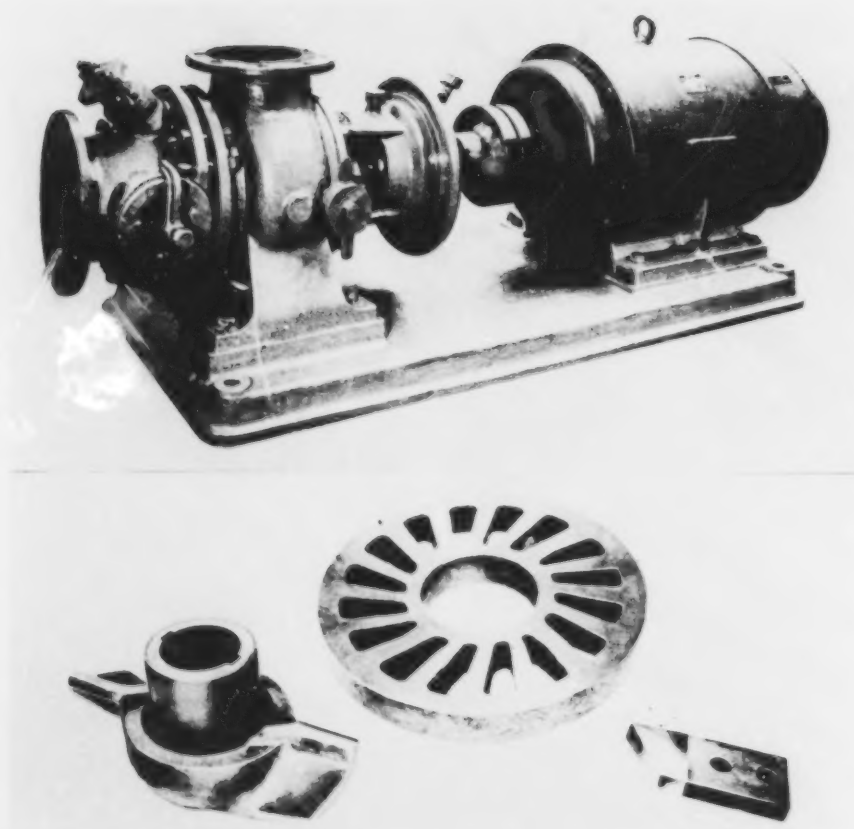


FIGURE 6. Sulzer Disintegrator

- a The "Wemco" pump is equipped with a recessed impeller which allows the unrestricted passage of solids up to 4 in through the pump.
 - b The "Gorator" pump has a wobble plate rotor which accepts particles which will pass through the piping. It may be provided with or without cutters for grinding. (Figure 7)
 - c Air lifts, screw pumps, and gravity are sometimes employed to transfer sludges.
- 2 Thickened sludges must be pumped with positive displacement units which have high suction and discharge head capabilities. Thickened sludges may have up to 1 foot head loss per foot of pipe.
- a The plunger or piston pump is most commonly employed since it has readily accessible large ball or flap valves operating upstream and downstream from a reciprocating cylindrical plunger. The pump may be either simplex or duplex. (Figure 8)
 - b Diaphragm pumps are similar in concept to the plunger pumps except that a pneumatic or hydraulic actuated diaphragm is used for displacement.
 - c The "Moyno" pump is a progressing cavity unit having excellent suction and discharge capability. The flow is discharged evenly. (Figure 9)

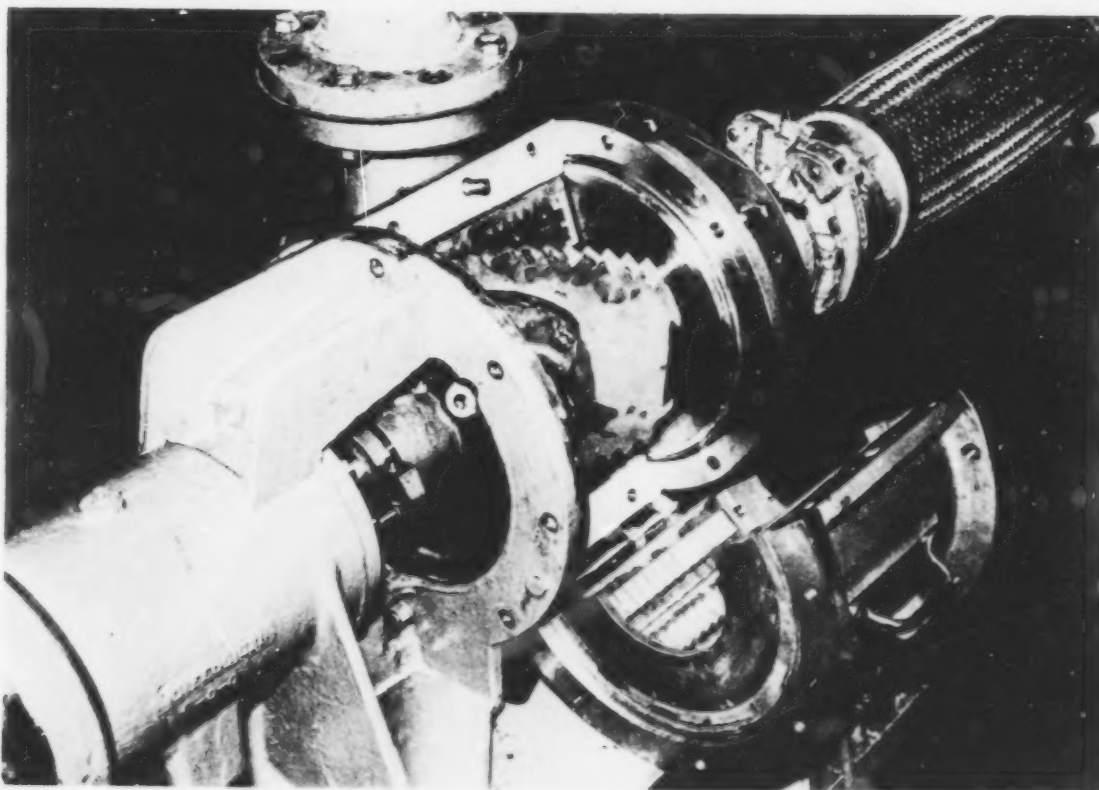


FIGURE 7. Gorator

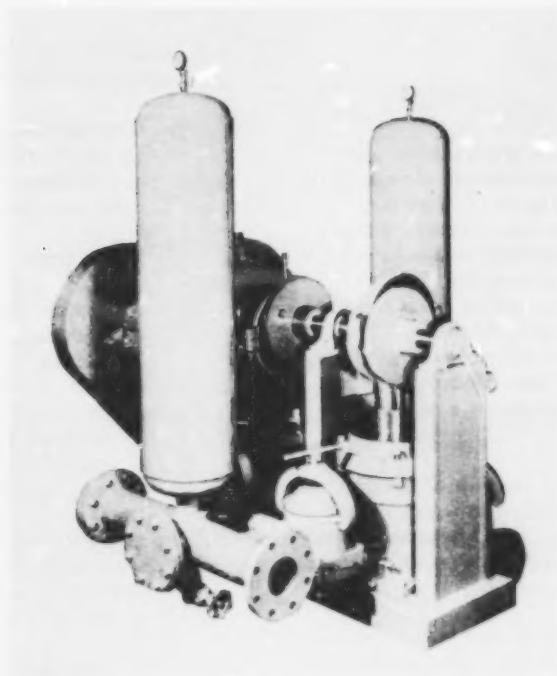


FIGURE 8. Sludgemaster

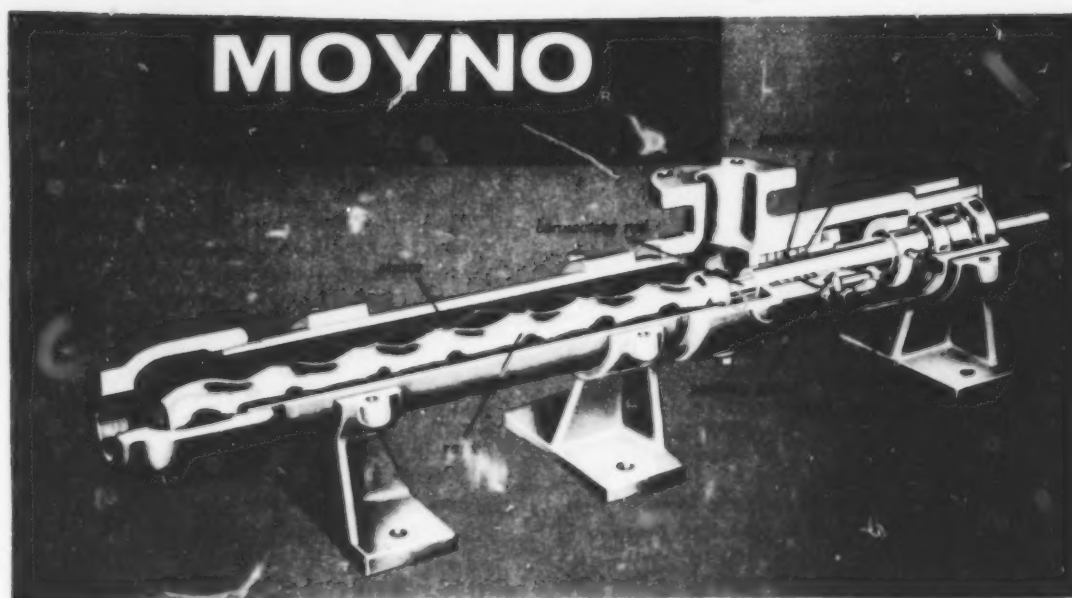


FIGURE 9. Moyno Pump

III SLUDGE DIGESTION

A Anaerobic Digestion

The anaerobic digestion process is accomplished in the absence of air by bacteria which converts 50-75% of the organic material to gases, carbon dioxide and methane. The residual solids properly digested are stable and non-putrifying. The process is carried out in enclosed tanks generally circular in construction. The process may be either single or two-stage providing 15-30 days detention in the first stage and the required storage in the secondary stage.

1 Floating covers are available manufactured of metal or combination of wood and metal and are designed to float inside the exterior walls directly in contact with the tank contents. (Figure 10)

- a The contact between the cover and the liquid keeps floating solids submerged thus reducing the formation of scum.
- b Weights are added to the cover to obtain the desired pressure and a relatively constant gas pressure is maintained.
- c Constant contact of the cover with the digester contents permits independent additions and withdrawals and minimizes the danger of oxygen mixing with digester gas to form an explosive mixture.

2 Fixed covers are usually conical or spherical domes made either of concrete placed integrally with the exterior walls or metal fastened to the walls. (Figure 11)

- a Fixed cover digesters have a lower construction cost than floating cover digesters.
- b The formation of scum is prevented by mechanical or gas mixing devices.
- c Positive displacement operation is required to minimize potential explosive mixture.

3 Auxiliary equipment is required to effect the digestion process.

a Heat exchangers, such as manufactured by the Pacific Flush Tank Company, are utilized to maintain sludge at the optimum temperature. (Figure 12)

1) Internal heating is accomplished by passing hot water through piping inside the tank. This approach is not commonly employed in newer plants.

2) In external heating sludge is withdrawn from the digester, circulated through a heat exchanger and returned to the tank.

b Digester tank mixers prevent scum formation and aid digestion. Generally mixing is provided only in the first stage digestion tank.

1) Gas mixers recirculate digester gas under compression through the tank contents.

2) Mechanical mixers are available in several designs including conveyor mixers, rotating paddles, scum breaker arms and scrappers, rotating spiral impellers and propeller mixers.

4 Miscellaneous equipment on the market include gas meters, flame arresters, gas pressure relief valves, sampling parts, auxiliary burners, liquid level indicators, manometers and supernatant level indicators, supernatant selectors, gas scrubbers, drip traps and vacuum breakers.

5 A commercially available adaptation of the anaerobic digester is the two story tank structure such as the Dorr-Oliver "Clarigester" or Yeoman's "Spirahoff", with the upper story being for sedimentation and the lower for digestion.

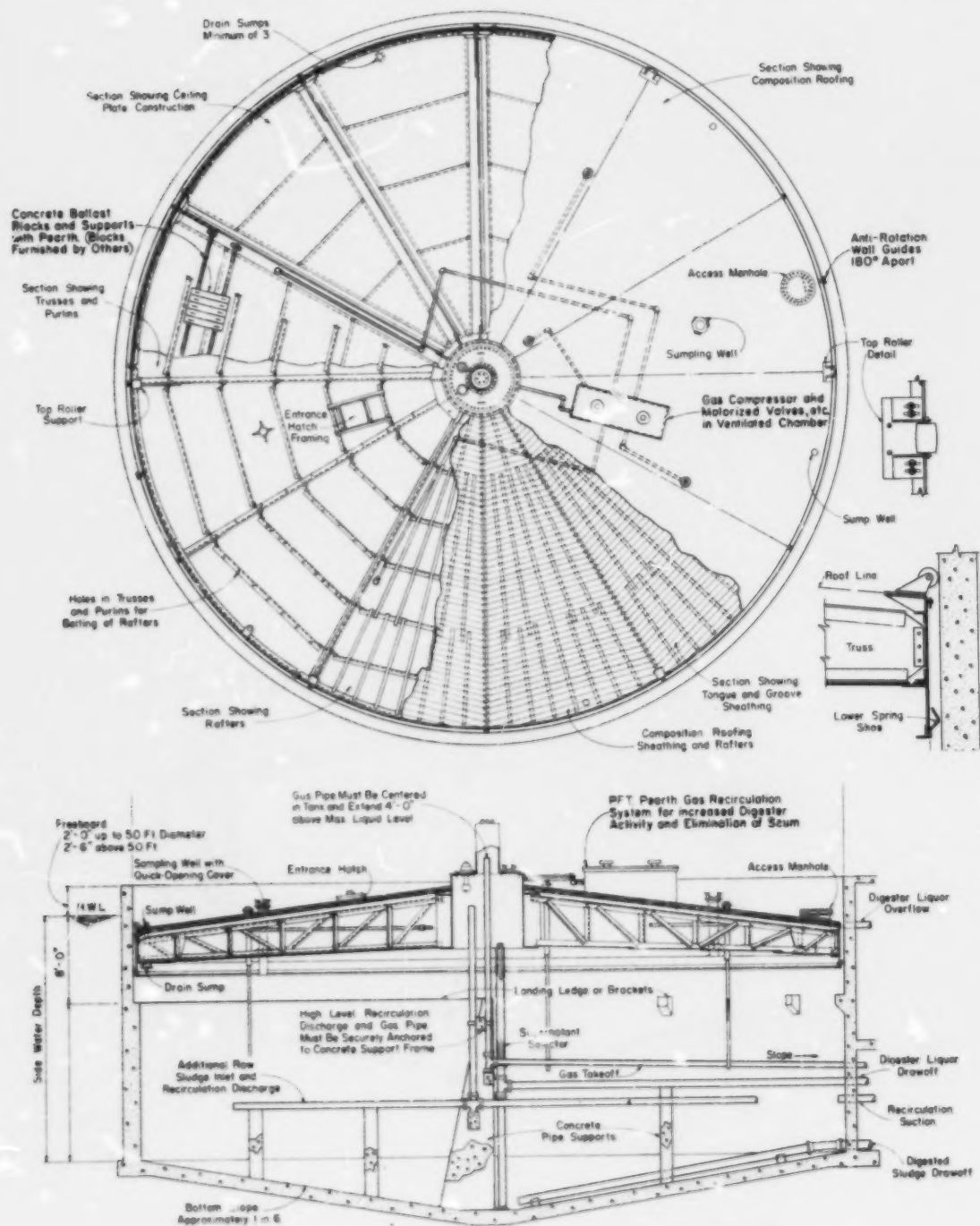


FIGURE 10. Floating Cover Digester With Gas Recirculation System
(Pacific Flush Tank Company)

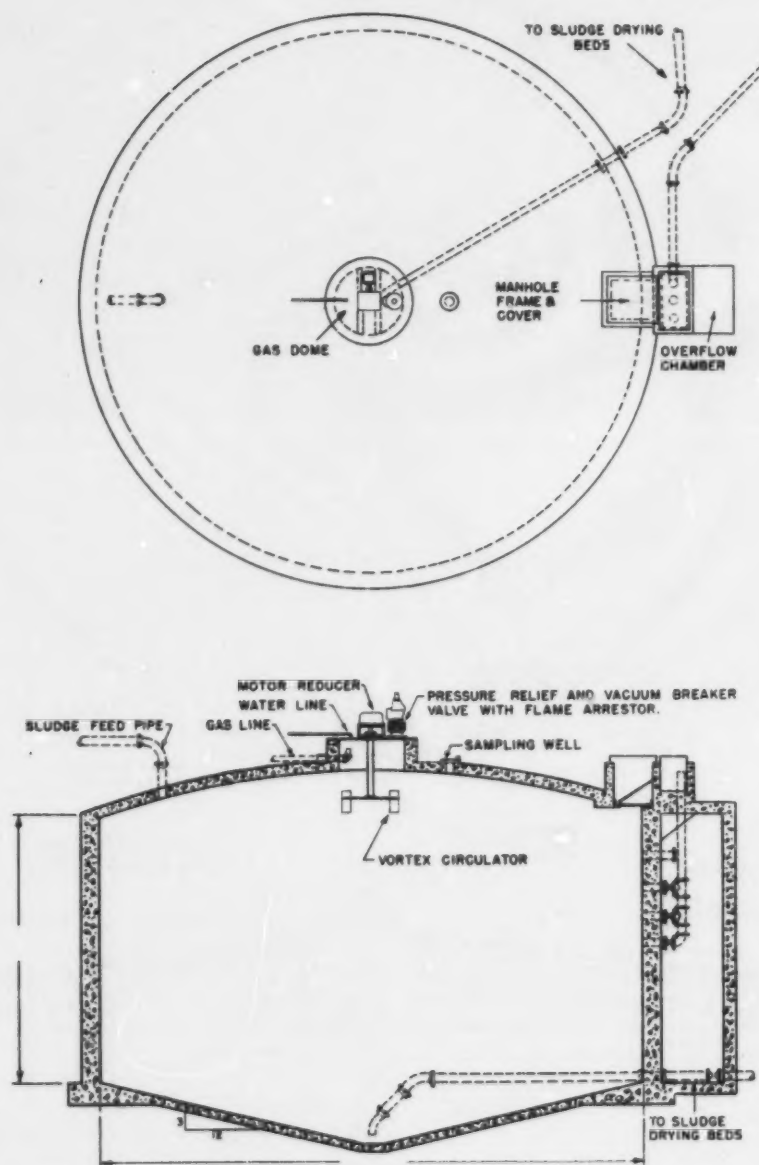


FIGURE 11. Infilco VC Digester, Fixed Cover with Mechanical Mixing

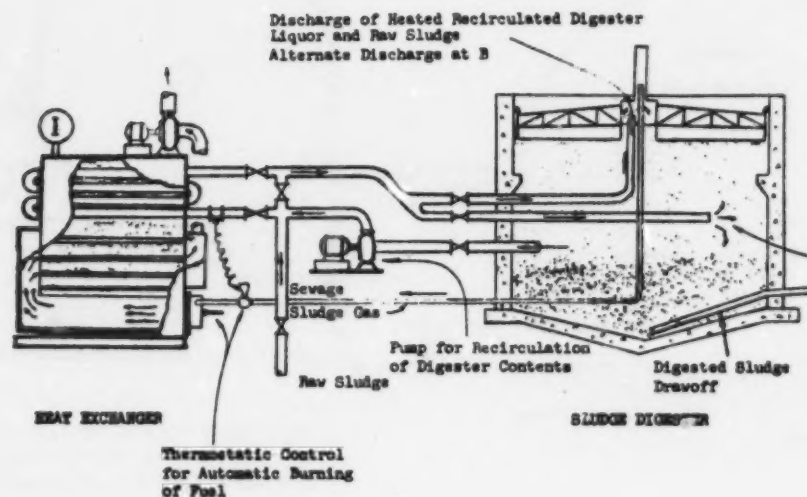


FIGURE 12. Digester Heating System (Pacific Flush Tank)

B Aerobic Digestion

Aerobic digestion of sludge is accomplished by aerating the sludge over an extended time period. The detention period is generally 15-30 days. Decanting of the excess liquor may be provided.

- 1 This process is commonly used in package plants but has also been used in conventional plants.
- 2 Diffused air is most common means for aeration but mechanical aeration is gaining acceptance due to low maintenance and high oxygen transfer efficiency.
- 3 Digesters may be either single-stage or two-stage operation.
- 4 While aerobic sludge settles to 3% TS readily, it becomes difficult to dewater mechanically particularly during winter operation.

IV SLUDGE DEWATERING

- A The mechanical dewatering of the waste sludge, whether raw or digested, is the major operation and economic burden in a treatment plant. Sand beds are employed in most of the plants now in operation, but new plants generally consider mechanical dewatering for plants serving over 20,000 population. The increasing population and desire to improve our aesthetic surroundings will be reflected in the diminishing use of sand beds. High cost of manual cleaning is also a factor.
- B Vacuum filtration is at the present the most commonly used method for mechanical dewatering of sludges. The design has evolved from a drum filter with scraper design to belt filter where cake is discharged by the filtration media separating from the drum and passing over a discharge roll. (Figure 13 and 14)

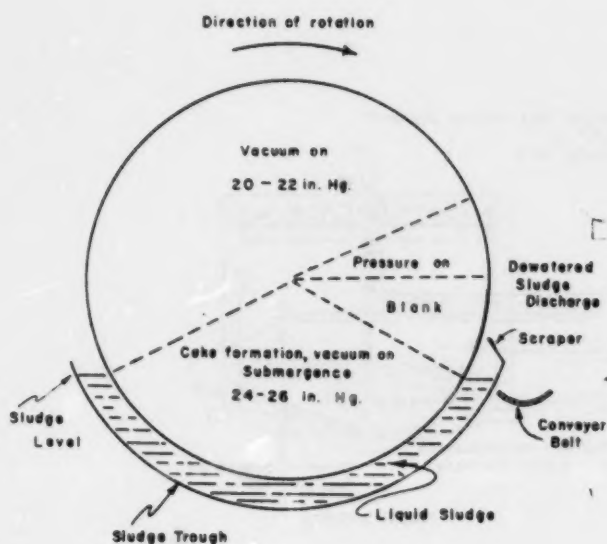


FIGURE 13. Vacuum Filtration Cycle Drum Filter

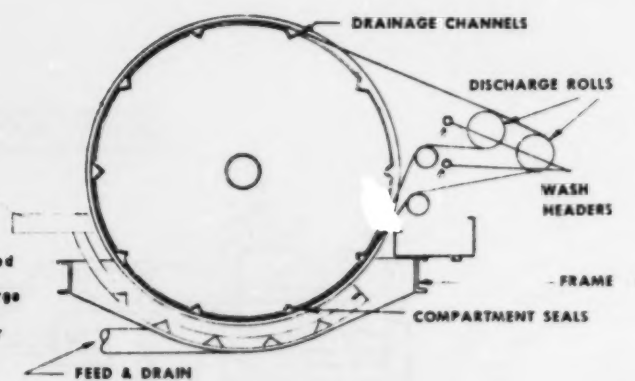


FIGURE 14. Komline-Sanderson Coilfilter

Vacuum filters require a conditioning agent to aid the dewatering process. Organic Polymers are replacing ferric chloride and lime which have been used in most plants. A summary of operating results from vacuums is shown below:

TABLE III
OPERATING COSTS FOR VACUUM FILTRATION

Sludge Type	Yield lbs/sq ft/day	Small Plants		Large Plants	
		Chemical Dollars per Ton (\$/ton)	Total Dollars per Ton (\$/ton)	Chemical Dollars per Ton (\$/ton)	Total Dollars per Ton (\$/ton)
RP	6.9	7.00	17.50	3.00	7.50
DP	7.2	11.50	38.70	5.50	13.75
R (P + H)	7.1	10.20	25.50	6.50	16.30
D (P + H)	5.3	21.50	53.80	9.50	23.80
R (P + AS)	4.5	-	-	10.50	26.20
D (P + AS)	5.6	13.00	32.50	12.50	31.25

R = Raw
P = Primary
D = Digested

H = Humus
AS = Activated Sludge

- 1 The vacuum filter is basically a hollow metal drum rotating slowly, partly submerged in a tank containing the sludge to be dewatered.

An agitator maintains the conditioned sludge solids in suspension.

- 2 The drum is divided into compartments covered by a woven wire or metal grid to support the filtering medium. Each compartment is connected by piping to vacuum and pressure systems. As the drum rotates, vacuum is applied to the compartments entering the sludge, causing sludge to adhere to the filter material. When the compartments reach the point of discharge the vacuum is released and pressure (air blow) is applied to aid in removing the sludge cake.
- 3 The cake is usually removed by blade or wire scrapers, or by a filter belt or coils which separate from the drum and carry the sludge over a discharge roller.

- 4 The separated liquid, or filtrate, is returned to the plant influent. The discharged cake drops to a conveyor or to a hopper for disposal.

- 5 The filtering medium may be of cotton, wool, hemp, stainless steel wire, or synthetic fibers including rayon, nylon, orlon, dacron, saran, teflon and dynel. The Komline-Sanderson "Coilfilter" is equipped with two layers of coil springs as the filter medium.

C Centrifugal dewatering of waste sludges is accomplished by settling the solids in a high gravity field generated by a rotating bowl. The bowl is fitted with an internally contoured screw conveyor (scroll) which continually discharges the solids. The pool and the dry deck are adjusted to satisfy the process requirements. Primary sludge is dewaterable without chemicals, while cationic polymers are used to produce a clear overflow (centrate). Summary of operating data accumulated from over 70 tests is as follows:

TABLE IV
CENTRIFUGE OPERATING DATA

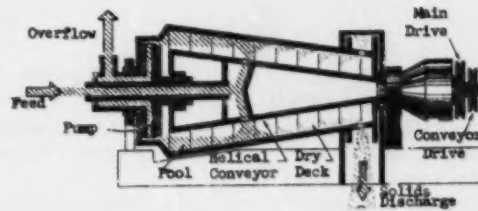
Sludge Type	Cake Solids % TS	Recovery %	Chemical Cost \$/Ton Dewatered Sludge
Primary	30-35	85-90	-
" *	30-35	95 +	3-5
Primary + Biofilter	22-26	70-80	-
" *	20-26	95 +	6-20
Primary + Activated	20-24	60-75	-
" *	18-24	95 +	6-20
Activated	12-18	95 +	15-30
* Digested			

The centrifuge is rapidly gaining acceptance due to the minimal operator attendance required, low maintenance and space requirements, and reduced capital costs. Centrifugation will likely become the predominant method for sludge disposal based on the present alternatives for sludge dewatering. This is presently proven by the rapid increase in centrifuge installations since the advent of the "long-bowl" unit.

- 1 The improved "MercoBowl" introduced by Dorr-Oliver in 1964 is a cylindrical-conical design with a length to diameter ratio of about 2.9. The so-called "long-bowl" design greatly improved clarification capacity of the machine and it is employed on all types of waste sludges. About 120 installations were sold between 1964 and 1968 in the waste treatment field. (Figure 15)
 - 2 The Bird Machine Company manufactures units similar in design with a length to diameter ratio of about 2.5. The "long-bowl" designs are offered with either a counterflow or concurrent flow design. Since 1954 over 100 units have been placed in the waste treatment field.
 - 3 The centrifuge must be fed evenly and generally the "Moyno" Pump is used. Other auxiliaries include chemical tanks and feeding equipment along with the necessary starting controls.
 - 4 The starting requirements for centrifuges are severe and most manufacturers utilize special high-torque star-delta motors. Operating power is 0.5 - 0.8 hp/gpm of feed.
- D Other methods such as mechanical vibration of the sludge across a screen, plug concentrations, plate and frame pressure filters have been used but have not been widely accepted.

V SLUDGE CONDITIONING

- A Sludge is commonly conditioned with chemicals such as polymers to aid in the reduction of the bound water content. The chemical conditioning equipment is provided for either vacuum filters or centrifugation. Chemical tanks generally include a mix and a use tank. Variable speed chemical pumps are provided.
- B The Purifax Corporation has developed a chemical oxidation process for treating sludge (Figure 16). It is claimed that this process can be used for treating raw or partly digested sludge before final disposal as well as for conditioning sludge prior to other processes.
- 1 The unit consists of a horizontal cylindrical reactor, with feed and process pumps and provision for the addition of diffused chlorine.
 - 2 Sludge is pumped to the reactor and chlorine, the oxidizing agent, is added with turbulent mixing.
 - 3 The process pumps circulate the sludge through mixing with the chlorine under a pressure of 35 psi.
 - 4 After a predetermined period of time, sufficient to achieve "breakpoint oxidation" and usually no more than two minutes, the material is discharged from the unit with a small amount being recirculated to condition the incoming sludge.
 - 5 There is no solids reduction, but the treated solids are claimed to be stable and settle well.
 - 6 The inert sludge can then be disposed of on sand beds in lagoons or by mechanical dewatering.



The Mercobowl Centrifuge Flow Diagram

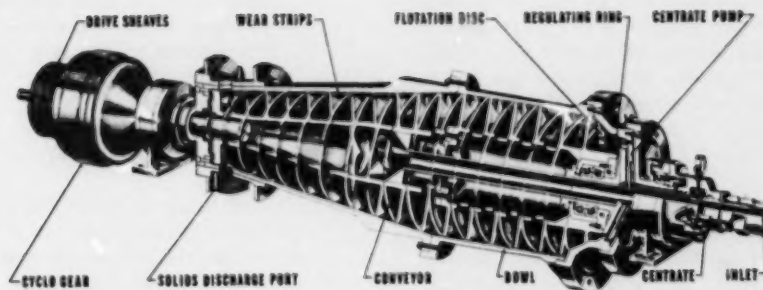


FIGURE 15. Mercobowl Conveyor Centrifuge

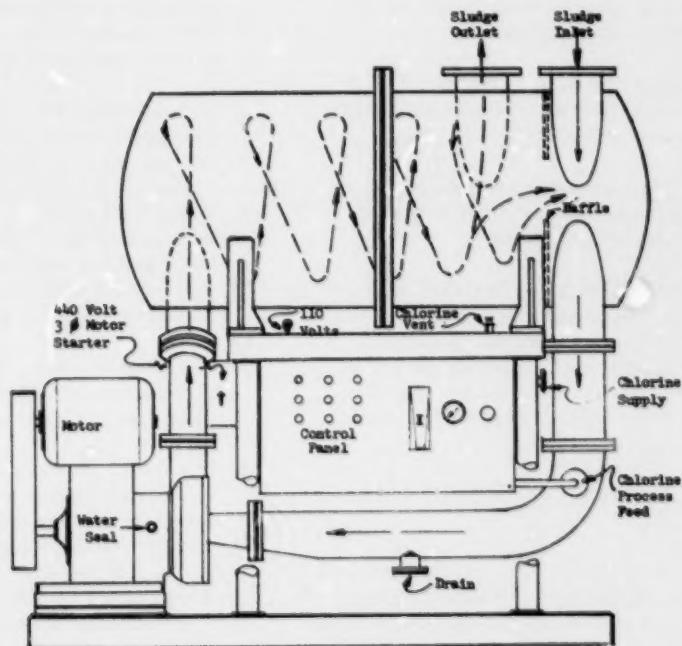


FIGURE 16. Purifax System

C The low oxidation Zimmerman Process utilizes pressure, temperature and a small amount of air to condition sludge for dewatering. The heat treating and 10 to 15% oxidation of the organics reduces the moisture holding characteristics of the secondary sludges. (Figure 17)

- 1 Sludge is ground, and then pumped at high pressure through heat exchangers to the reactor. Compressed air is fed into the system with the sludge.
- 2 The air entrained sludge, under pressures from 150-450 pounds per square inch gauge (psig) and at temperatures from 400° F or higher, passes upward through a series of baffles where partial oxidation takes place. Super-heated steam is injected into the reactor to make up losses.
- 3 The effluent passes through the heat exchangers and then to a separator for removal of the gas from the liquid and ash.
- 4 The gas is passed through a catalytic oxidation unit and discharged to air.
- 5 The residual solids equal to 60-75% of the feed may be dewatered on sand beds or by vacuum filtration.
- 6 A batch-type plant is available for use by the smaller community where one shift per day is desirable.

D The Dorr-Oliver "Farrer System" is a heat treatment process employed to break down the bound water content of secondary sludges reducing or eliminating chemical costs. The system is an improvement on the original Porteous Process developed in England. (Figure 18)

- 1 Sludge is degrittied, ground and thickened to 5-8% TS.
- 2 The feed is preheated by the treated exit sludge through indirect heat exchange and then boosted to the operating temperature of 380-400° F.

3 A plug flow reactor is provided with 30 minutes detention and then discharged after heating incoming sludge. About 85% heat recovery is possible.

4 The treated sludge can be settled to 12-15% TS and the liquor decanted and returned to process. The liquor contains a BOD equal to 10-15% of the plant influent, but is readily reduced.

5 Sludge may be dewatered by sand beds or mechanical means. Filter presses used in Europe obtain 50-65% TS, vacuum filter tests indicate 45-50% TS without chemicals on primary and activated sludges.

VI ULTIMATE DISPOSAL

A The ultimate disposal of sludge in a safe and appropriate manner must be the most important consideration in the selection of treatment process.

B Liquid sludge, both raw and digested, has been hauled or piped to remote areas for land reclamation. There is mixed acceptance of this method.

C Dried sludge has been extensively used for soil conditioner or landfill. When bagged for sale it is dried to approximately 10% moisture content. Rotary dryers pass dewatered sludge, constantly in contact with heated air, through a rotating horizontal drum. The heat must be controlled to avoid burning or scorching. Market is limited and costs are high.

D Barging or piping of digested sludge for disposal at sea may be feasible at some of the larger coastal cities.

E The large amount of combustible materials in sewage sludge makes incineration feasible particularly when the moisture content can be reduced below 65%. Many plants, large and small, are employing the process as the answer to minimizing waste solids derived from treating sewage. Combustion of the organics will leave

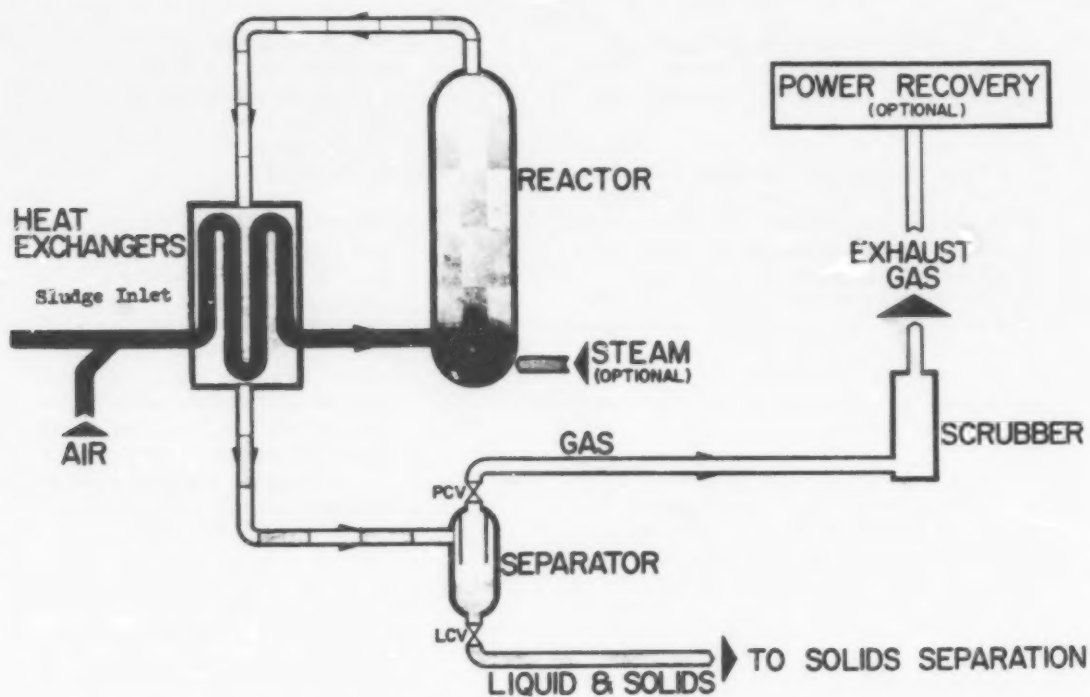


FIGURE 17. General Flow Diagram Zimpro Sludge Oxidation

Flow Sheet

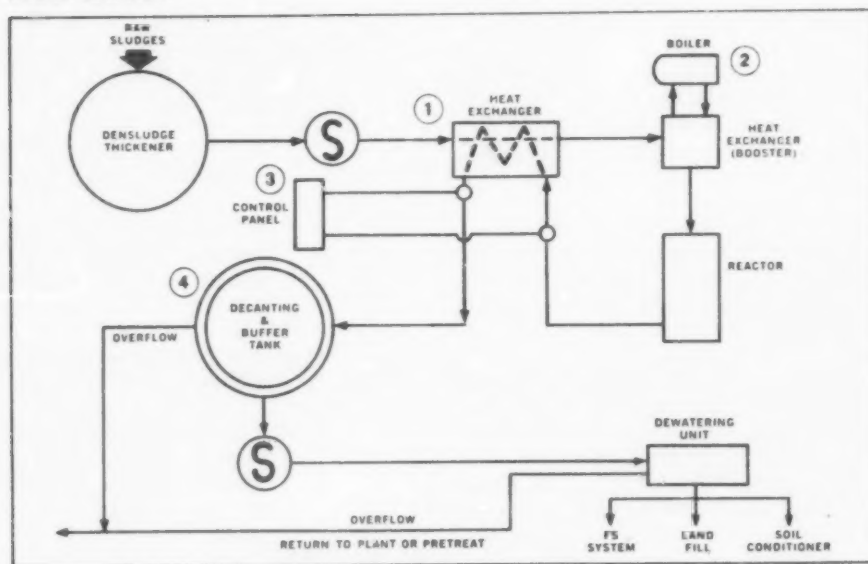


FIGURE 18. Dorr-Oliver Farrer System

about 4 cubic feet per million gallons (cu ft/mil gal) of ash for disposal. The ash compacts well and is acceptable for stable landfill.

The 100% increase in the rate of combustion system construction over the past four years can be attributed to several factors. Of these, on-site disposal requirements, limited plant space, new and simpler equipment designs and more economical operation are most important. Odor control is most important and all manufacturers will offer their equipment with high-temperature deodorization or low temperature catalytic oxidation.

F There are a number of approaches to the problem of combusting wet sludges. The oldest acceptable method is the multiple hearth furnace while in recent years wet oxidation and fluidized-bed combustion have been employed. To a minor degree rotary kilns and burning sludge in a municipal refuse incinerator has been applied for sewage sludge disposal.

1 The multiple hearths, manufactured by Nichols Engineering and Research and Bartlett-Snow-Pacific, may be used for either drying or incineration of sludges. (Figure 19)

a The furnace consists of a refractory-lined, steel-jacketed, circular unit with four or more arch-supported brick hearths located one above the other.

b The hearths are rabbled by high-temperature-resistant metal arms projecting from a rotating center column which is driven by a motor mounted below the reactor.

c Sludge is fed into the top hearth and rabbled in the presence of hot combustion gases until it falls into the hearth below. The action continues until the solids content of the sludge will support combustion. In a typical unit there may be 3 drying hearths, 2 combustion and 1 cooling.

d Where strict air pollution codes are in effect, it may be necessary to provide an additional hearth at the top of the reactor and install a burner which raises the exit temperature to 1350-1400°F.

e The combustion gases are scrubbed and cooled to remove particulate matter and the balance of the ash discharged from the lower compartment.

f Air is forced through the center column and out the rabble arms for cooling and then used for combustion. The exhaust fan is employed to maintain a slightly negative pressure in the furnace and individual hearth openings regulate draft.

2 The "Zimpro System" for complete oxidation operates at 1200-1800 psig, but otherwise is similar to the previous flowsheet. The unit is capable of reducing the COD of the waste by 70-90%. A system of this type was installed in Chicago in 1960-62, but recent units are employed for sludge conditioning.

3 The Dorr-Oliver "FS System" provides for sludge preparation and combustion of dewatered sludge in fluidized bed of sand. (Figure 20)

a Raw sludge is degritt and then conditioned in a sludge thickener.

b After pulverization in a disintegrator, polymer is added and the sludge is dewatered in a centrifuge or a vacuum filter.

c The dewatered material is fed into a fluidized bed of sand in the reactor.

d The reactor consists of a steel shell with a unitized brick lining with no moving parts. Air is distributed to the bed of sand through a constriction plant.

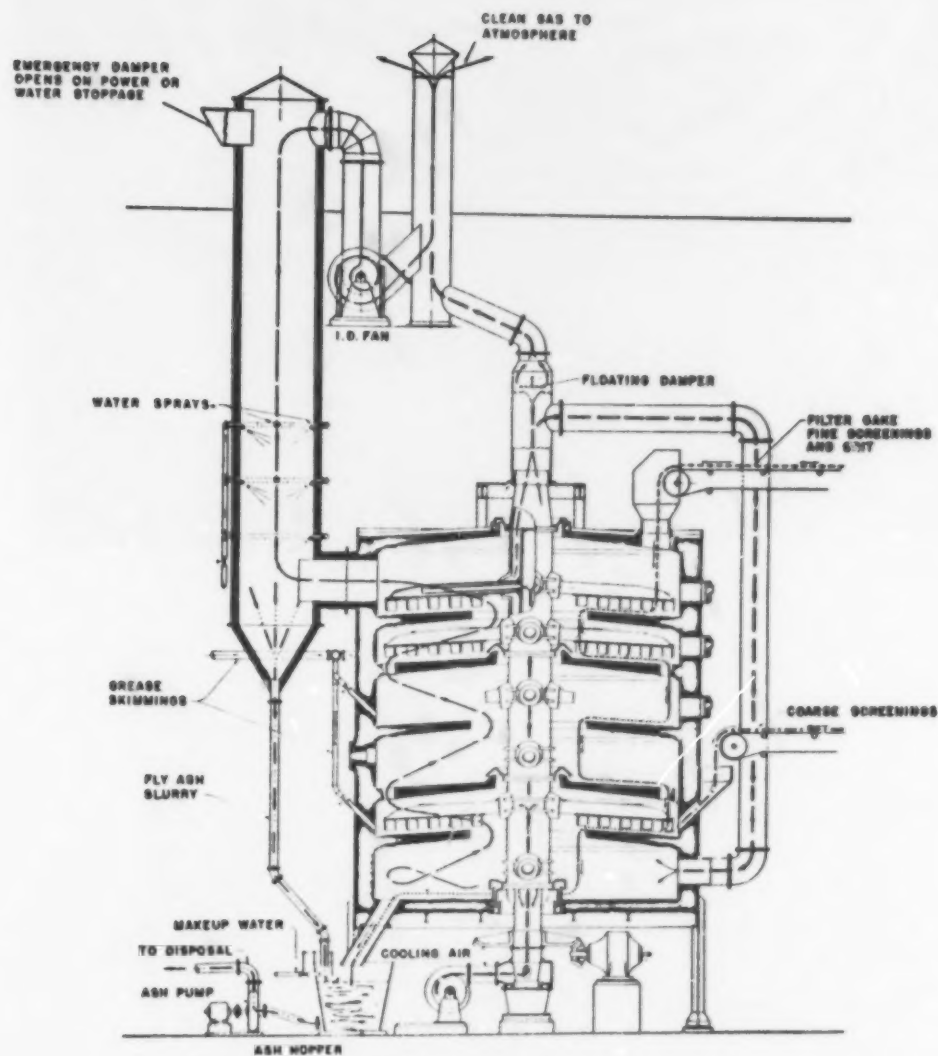


FIGURE 19. The Multiple-Hearth Furnace

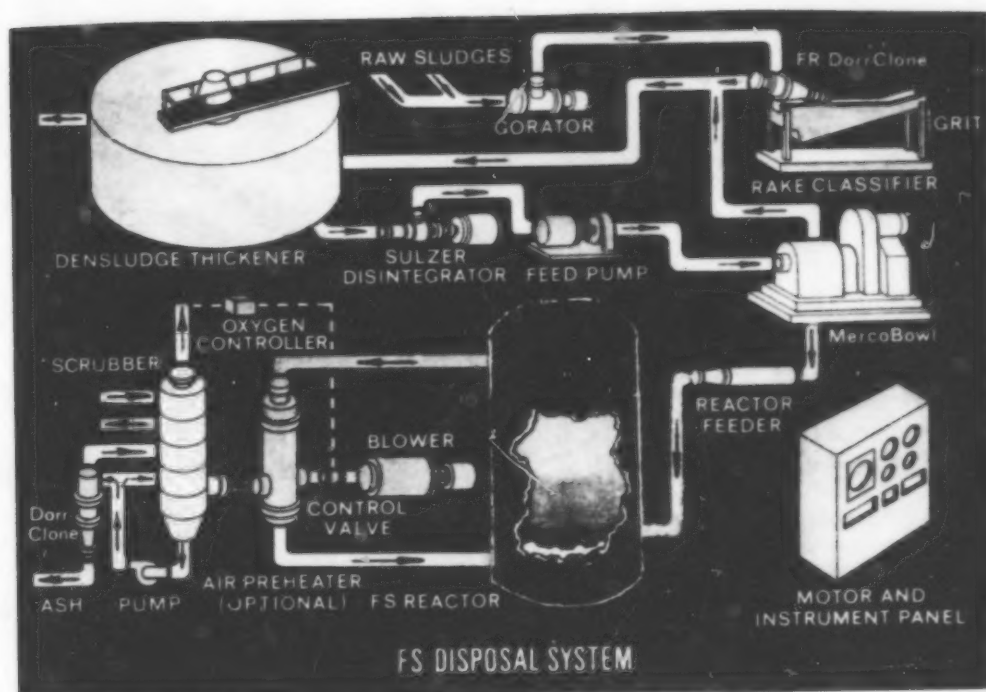


FIGURE 20. Dorr-Oliver System for Fluidized Bed Sludge Combustion

- e The upward flow of the air used for fluidization of the sand bed and for combustion carries the inert ash out of the reactor.
- f Ash removed from the reactor is separated from the flue gases by a liquid scrubber.
- g The ash in the scrubber underflow can be disposed of in a settling lagoon or tank or by dewatering with a hydro-cyclone.
- h Auxiliary fuel, either oil or gas, is used to supply initial heat and to insure that the reactor temperature is maintained at approximately 1500° F. Downtime heat loss is 7-10° F/hr.
- i The FS System Type CR by Dorr-Oliver is a compact pre-assembled sludge combustion system for use by smaller communities.

- j The "Farrer System" used with the "FS System" will eliminate about 70-80% of the fuel, chemical and power costs associated with sludge combustion.

VII. CONCLUSIONS

- A The present technology of sludge disposal is rapidly being expanded by new approaches demanded by the problems associated with the handling and disposal of solids derived from waste treatment.
- B The multiplicity of equipment involved requires the integration of processes and unit operations to provide means for the effective and economical handling of waste solids. This will evolve waste solids handling systems such as the Dorr-Oliver "Farrer-FS System" which reduces the chemical, fuel, power and attendance costs associated with dewatering-combustion from \$25-35/ton to \$7-15/ton dry solids.

C No choice of equipment or processes can be considered adequate which does not give careful attention to several factors.

- 1 Safety - both Public Health and operational characteristics
- 2 Present and foreseeable future requirements of the Regulatory Bodies
- 3 Economy of design and operation
- 4 Aesthetic values
- 5 Functional efficiency with minimal complexity

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Burd, R.S. A Study of Sludge Handling and Disposal, Contract No. PH 86-66-32 for the FWPCA. June 1966.

This outline was prepared by W. L. Carter, Deputy Construction Grants Program Director, Middle Atlantic Region FWPCA, Charlottesville, VA, and revised by Orris E. Albertson, Marketing Manager, Water Management System, Dorr-Oliver, Inc., Stamford, Connecticut.

BASIC PRINCIPLES OF VACUUM FILTRATION

I INTRODUCTION

A The process of vacuum filtration, originally borrowed from the chemical industry, is one of the most widely used methods of mechanical sludge dewatering. It is applicable to both raw and digested sludges and, in view of high labor costs and small space requirements, it is an economical method of sludge drying for many installations.

B In very general terms a description of the vacuum filtration process can be given. Sludge with a moisture content in the range of 94% to 98% is transported to a tank. Rotating in this tank is a drum covered with a porous filter media. The drum is rotated in the wet sludge with about one-quarter of the drum submerged. Mechanically, the drum is arranged so that vacuum is applied to the inner side of the drum and wet sludge is drawn against the filter media. As the drum rotates a layer of sludge is held to it. When this layer is free of the liquid sludge tank the continued application of the vacuum draws water from the sludge through the filter media leaving a mat of moist sludge cake on the media. This mat is removed by various means and the media cleaned before it re-enters the sludge tank. The sludge cake may contain 60% to 85% moisture at this time but is easily handled. Activated and raw sludges present more difficult handling problems than digested sludges.

C The common performance criteria for vacuum filters is pounds per hour of dry solids produced per square foot of filter surface, or weight of dry cake solids per unit volume of filtrate. A number of variables affect this performance.

II VARIABLES

A Sludge concentration or weight of volume of filterable solids per unit volume of unfiltered sludge will affect the amount of

sludge solids to be obtained from a filter. This variable is controlled by the processes used to create and collect the sludge and any prior thickening processes that may be employed. In design of a new facility, it must be derived from prior computations. If a vacuum filtration process is being added to an existing plant sludge concentration can be measured.

B Sludge processing rate is the amount of sludge to be processed and is a function of the plant's size and loading. In a large plant sludge flow is most often continuous to the vacuum filtration process. Small plants having adequate vacuum filtration capacity may use the process during one shift several days per week. The sludge processing rate is then the amount of sludge per unit of time being brought to the filter. It is usually expressed in cubic feet per hour (or cubic meters per hour).

C Time of filter cycle, that is the time required for the drum to make one complete revolution, affects the rate of filtration. Cake thickness decreases as cycle time is reduced so that drum speed is usually controlled by the minimum removable thickness of filter cake.

D Drum surface area available affects the amount of sludge that can be processed.

E Weight of solids concentration in filter cake varies depending on the unfiltered sludge, the filterability of the sludge, the filter cycle time and the efficiency of the filter.

F Vacuum pressure applied to the filter will affect the amount of cake that the filter can "pick up". Pressure is often expressed as pressure difference with atmospheric.

G Flow resistance of the filter media will affect the amount of water that can be drawn from the cake in a given time. With proper media selection this resistance is usually negligible compared to the

resistance of the filter cake.

H Filter cake resistance can be related to the cake permeability. The rate at which the filtrate flows through the filter cake per unit of time affects cake moisture content. Cake permeability depends on cake porosity, average specific cake particle area and compressibility. It has been found most convenient to utilize filtration resistance of the cake to express these properties.

I Viscosity of the extracted fluid will affect the rate of filtration. The fluid is almost always water for waste disposal work in filtration.

J Temperature of the sludge to be dewatered affects the viscosity of the extracted fluid.

III VACUUM FILTER DESIGN

A The usual problem in filter design is to determine the filter area required. This determination is necessary so that a proper selection of vacuum filter unit(s) can be made.

B The information required to make this determination is:

- 1 Sludge concentration as % of filterable solids to be dewatered - w
- 2 Sludge processing rate as cubic feet per hour to be filtered - V
- 3 Time of filter cycle in minutes or seconds - t_c
- 4 Liquid sludge density in pounds per cubic foot (usually taken to be the same as water - ρ)
- 5 Weight of solids concentration in filter cake as a percent - x_c
- 6 Weight of solids concentration in unfiltered sludge as a percent - x
- 7 Vacuum pressure - inches Hg or pounds/ft²

8 Portion of cycle time utilized in forming the filter cake (portion of time that unit is in sludge tank) as a fraction - α

9 Liquid viscosity - μ

10 Resistance of filter cake in seconds per pound - R

C The information is used as follows:

1 Determine wt. of solids filtered/second

$$\frac{Vw}{t_c} = \text{pounds/sec.}$$

2 Determine the wt. of solids/unit volume of filtrate

$$w_f = \frac{\rho}{\left[\frac{(1-x)}{x}\right] - \left[\frac{(1-x_c)}{x_c}\right]}$$

3 Determine filter yield, B , lbs (ft²)(sec.)

$$B = \left[\frac{2(\Delta p) w_f \alpha}{\mu R t_c} \right]^{\frac{1}{2}}$$

4 Filter area required, S , is determined

$$S = \frac{Vw/t_c}{B}, \text{ ft}^2$$

IV VACUUM FILTER SLUDGE TESTS

A If a vacuum filter unit is added to an existing plant or if a change occurs in the sludge being filtered (e.g., adding or changing conditioning chemicals) tests may be run on the aqueous sludge to determine its filtering characteristics. These results in turn, may be used to perform vacuum filter design calculations.

B These tests would include:

- 1 Determination of solids per unit volume of filtrate and,
- 2 Vacuum filtration tests with a known temperature, filtration vacuum pressure, filter area and the value of 1 above.

C The results of the vacuum filtration test would be filtrate volumes (V) obtained after various time periods (t). This information is used to:

- 1 Plot a series of values of t/V versus corresponding V values.
- 2 Determine the slope of the straight line of best fit for the plotted data.
- 3 Determine the specific resistance of the filter cake, R as follows:

$$R = \frac{2 k_s S^2 \Delta p}{\mu w}$$

where k_s = the slope (constant) determined

V HORSEPOWER AND OTHER COSTS

A While no standard formula can be given the horsepower required for operation of vacuum filters can be roughly computed as $1/8 \text{ HP/ft}^2$ of filter area.

B Because vacuum filtration requires less space and is applicable to non-digested sludges with final sludge disposal handled by other means (e.g., burial in landfill, incineration) eliminating digestion it may require economic analysis to determine what process is economically best to use for a given plant.

VI CONVERSION FACTORS

inches of Hg $\times 70.73 = \text{lbs./square ft.}$

viscosity in centipoise $\times 6.72 \times 10^{-4} =$
viscosity in lb/ (ft) (sec)

square centimeters $\times 1.076 \times 10^{-3} =$
square feet

grams/liter $\times 0.062427 = \text{pounds/cubic ft.}$

This outline was prepared by Robert Roth, Chief, Technical Training, Southeast Water Laboratory, Athens, Georgia.

SLUDGE COMBUSTION

I INTRODUCTION

A Incineration of municipal and industrial refuse has been a standard practice for many years. The combustion of semi-solid sewage and industrial waste sludge is a relatively recent innovation. Dearborn, Michigan, installed the first full-scale sewage sludge incinerator in 1935.⁽²⁸⁷⁾ 2

Sludge combustion is becoming increasingly popular as land areas for sand beds, lagoons, and landfills become more difficult to find and more expensive. The land situation is magnified by ever-increasing volumes of sludge to dispose of and by the encroachment of urban neighborhoods on land disposal areas. There is no doubt that sludge combustion will in the future be adopted by more and more industries and cities because it represents a sanitary method for ultimate sludge disposal (at least for the organic portion of the sludge) in a relatively small land area. For many industries and cities, incineration will provide the only practical answer to sludge disposal.

B Incineration is practiced for two basic purposes, volume reduction and solids sterilization. Fulfilling these purposes is expensive and it may cause an air pollution problem. But the economics of combustion appear more favorable each year as the alternative sludge disposal methods become more expensive. Air pollution problems can be solved by proper equipment design and operation.

II SLUDGE CHARACTERISTICS

A Russell says the following sludge parameters are most important in the incineration process: (1) moisture, (2) volatiles, (3) inerts, and (4) calorific value.^(65d) 2 Of the above, moisture is the principal characteristic over which the treatment plant operator has some control. Moisture is generally reduced by mechanical sludge-dewatering techniques before incineration. It is important because of the thermal load it imposes on the incineration process with consequent effects on self-sustained sludge combustion.

B Volatile and inert materials affect the calorie or Btu value of the sludge. They are, to some extent, controlled by other

treatment processes such as degritting, mechanical dewatering, and sludge digestion. Almost all of the combustibles are present in the sludge as volatiles, much of it in the form of grease. The volatile percentage and, therefore, the heat value can vary widely, so incineration equipment must be designed to handle a broad range of values.

1 Table 19, 1 by Owen describes the most important incineration parameters for many of the solids generated at a sewage treatment plant.⁽³²¹⁾

2 As a general rule, the thermal value of sewage sludge is considered to be 10,000 Btu per pound of volatile solids. If the ultimate analysis is known, Owen claimed that the heat value can be precisely computed by using the DuLong formula:⁽³²¹⁾

$$Q = 14,600 C + 62,000 (H - \frac{O}{8})$$

where Q = Btu/lb.

C = % carbon

H = % hydrogen

O = % oxygen

III THEORY

A Incineration processes involve two steps: (1) drying and (2) combustion. In addition to fuel and air; time, temperature, and turbulence are necessary for a complete reaction. The drying step should not be confused with preliminary dewatering; this dewatering, usually by mechanical means, precedes the incineration process in most systems. A sludge, having a moisture content of about 75 percent is delivered to the most common types of incinerators. Since the typical sludge contains about 3 pounds of water for each pound of dry solids, the heat required to evaporate the water nearly balances the heat available from combustion of the dry solids.^(65d)

B Drying and combustion may be done in separate pieces of equipment or successively in the same unit. Manufacturers have developed widely varying types of sludge drying and combustion equipment. These include traveling-grate furnaces, rotary-kiln-type furnaces, fluidized-bed units, wet-oxidation units, atomized spray units, multiple hearth furnaces, and flash-drying units.

Table 19.1

Material	Combustibles (%)	Ash (%)	Btu/ Pound
Grease and scum	88.5	11.5	16,750
Raw sewage solids	74.0	26.0	10,285
Fine screenings	86.4	13.6	8,990
Ground garbage	84.8	15.2	8,245
Digested sewage solids and ground garbage	49.6	50.4	8,020
Digested sludge	59.6	40.4	5,290
Grit	33.2	69.8	4,000

The drying and combustion process consists of the following phases: (1) raising the temperature of the feed sludge to 212°F, (2) evaporating water from the sludge, (3) increasing the water vapor and air temperature of the gas, and (4) increasing the temperature of the dried sludge volatiles to the ignition point. (65d)

- C Practical operation of an incinerator requires that air in excess of theoretical requirements must be supplied for complete combustion of the fuel. The introduction of excess air has the effect of reducing the burning temperature and increasing the heat losses from the furnace. For this reason, a closely controlled minimum excess air flow is desirable for maximum thermal economy. The amount of excess air required varies with the type of burning equipment, the nature of the sludge to be burned, and the disposition of the stack gases.
- D Fuel (sludge) burned in a furnace emits heat; some is absorbed by the furnace and is lost by radiation, a larger portion is lost with the stack gases, and a smaller portion is lost with the ash. The difference between the heat generated and the heat lost is available for heating the incoming sludge and air. Self-sustained combustion is often possible with dewatered raw sludges once the burning of auxiliary fuel raises incinerator temperatures to the ignition point.
- E The primary end products of combustion are considered to be water, sulfur dioxide, carbon dioxide, and inert ash.

III TYPES OF FURNACE

In general, there are only three types of furnace capable of burning sewage sludge, including conditioned sludge resulting from the biological treatment of trade effluents. These are (a) the rotary drum furnace, (b) the fluidized-bed furnace, and (c) the multiple-hearth furnace.

A Rotary Drum Furnace (Figure 1)

This consists of an inclined cylinder with internal baffles which is rotated slowly by a toothed gear ring enshrouding the barrel. Sludge is admitted at the upper end and normally travels with the flow of heated combustion air. Ash and flue gases are discharged from the lower end of the drum and the exhaust gases contain about 20 per cent by weight of the ash. Because of structural difficulties in providing firebrick insulation inside the drum, the heat losses are high, which means that a well-dried cake must be produced by the preceding dewatering process in order to achieve autothermic incineration. In this state, no extraneous fuel is needed except for part-load operation or during startup.

B Fluidized-bed Furnace (Figure 2)

Fluidized-bed techniques have produced a compact form of furnace suitable for burning any material which can satisfactorily be fed to it, including sewage sludge. The bed of specially selected silica sand is maintained in a highly turbulent state by the combustion air and both the sludge and any supplementary fuel are fed directly into this zone. Combustion is completed in one or two seconds at a temperature of about 950°C.

Table 1

Effect of Moisture Level of Sludge on Auxiliary Fuel Requirement*

Per Cent Solids Wet Basis	Moisture Content Dry Basis (lb. water/lb. dry solid)	Auxiliary Heat Required (Btu/lb. dry solid)	Additional Cost (\$/ton dry solid)
15	5.67	5830	5.8
20	4.0	2500	2.5
25	3.0	500	0.5
30	3.33	-833	-
35	1.85	-1780	-
40	1.5	-2500	-

*Calculation is based on sludge with heating value of 5500 Btu/lb. of dry solids. Heating requirement is estimated from water content only, using 2,000 Btu/lb. of water. Fuel is estimated to cost \$0.50/million Btu.

With this type of furnace all the ash appears in the flue gases so that highly efficient gas cleaning is essential to maintain statutory requirements for gaseous discharges. Furthermore, it is necessary to incorporate a recuperative heat exchanger to pre-heat part or all of the combustible air. Since this exchanger has to handle flue gases at between 900°C and 1000°C, it is by no means cheap. It is not, therefore, economically justifiable to reduce the temperature of the exit flue gases below 700°C, which inevitably results in a poorer overall heat balance than that of the multiple-hearth incinerator.

The principal application of this type of furnace is for burning sludges with a significant content of highly volatile material such as those resulting from the treatment of oil refinery or chemical plant wastes. Its "all-up" cost is about the same as that of a multiple-hearth furnace installation for the same duty. However, it is not possible at present to build a fluidized-bed furnace with a capacity as large as that of the biggest multiple-hearth furnace, the chief obstacle being the difficulty of feeding the cake uniformly over the whole of the bed.

C Multiple-hearth Furnace (Figures 3 and 4)

This furnace consists essentially of a firebrick-lined, vertical, cylindrical shell with firebrick diaphragms or hearths set one above the other. Alternate hearths are centrally or peripherally

perforated to permit the simultaneous downward flow of burning material and upward flow of burning material and upward flow of combustion gases in true counter-current fashion. A central, hollow, air-cooled rotor is fitted with air-cooled, radial, hollow rabble arms and rabble teeth and this rotates slowly about the vertical axis. This ensures that all the solids passing through the furnace are continuously raked to facilitate even combustion. Because of the counter-current flow of solids and gases, automatic pre-heating of the combustion air takes place without the need for flue gas heat exchangers. Since only about 10 per cent by weight of the ash left by combustion appears in the flue gases, much less elaborate cleaning is necessary than with the fluidized-bed furnace.

1 Furnaces of up to 7 m (roughly 23 ft.) internal diameter can be built and from four to twelve hearths are normally specified according to the duty involved. Exit gas temperatures of between 300°C and 600°C are achieved, depending on the nature of the sludge being burned.

2 Because of a phenomenon known as "thermal jump," sewage sludge being burnt in a multiple-hearth furnace exists for only a very short time in the distillation range of temperatures in which offensive-smelling vapours are generated. Although the gas phase goes through a steady temperature reduction in its upward passage through

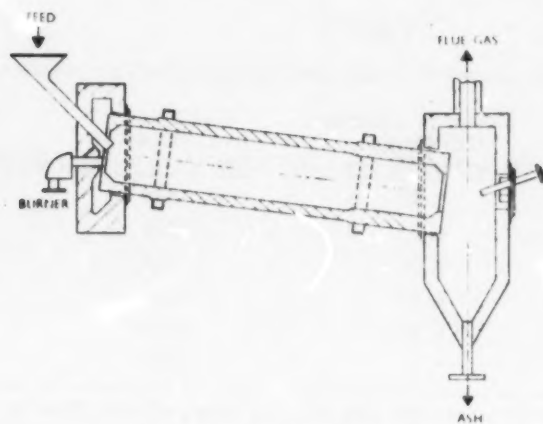


Fig. 1. Diagram of rotary furnace

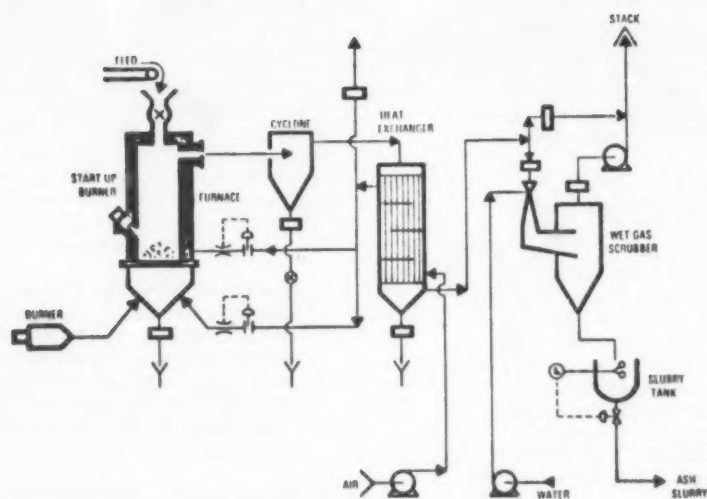


Fig. 2. Flowsheet of fluidized bed furnace

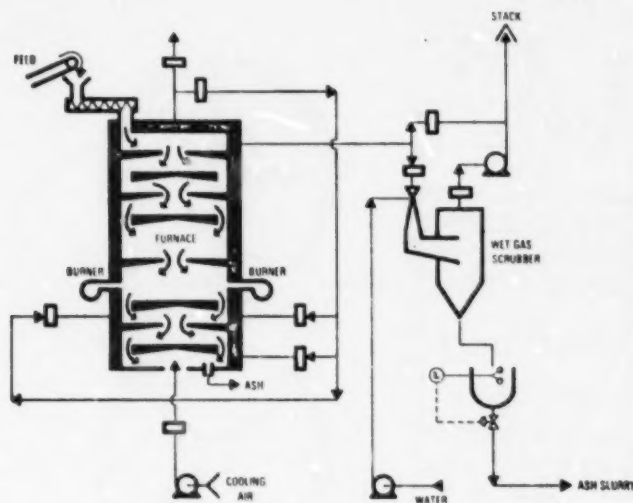


Fig. 3. Flowsheet of multiple-hearth furnace

the furnace, the descending sludge remains for most of its drying period at about 90°C because of the presence of water in the liquid phase. In the combustion zone the temperature rises rapidly to between 800°C and 900°C and essentially complete combustion takes place. The ash is normally characterized by an ignition loss at 800°C of less than 1 per cent by weight. It is odourless and sterile. Wetter sludges can be burnt more economically in a multiple-hearth furnace than in a rotary or a fluidized-bed furnace. Autothermic incineration can be achieved with undigested primary sludge containing about 30 per cent dry solids whereas approximately 40 per cent solids would be needed in a fluidized-bed furnace.

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This outline was prepared by J. B. Farrell, Chemical Engineer, Ultimate Disposal Research Program, Advanced Waste Treatment Research Laboratory, WQO, EPA Cincinnati, OH 45226.

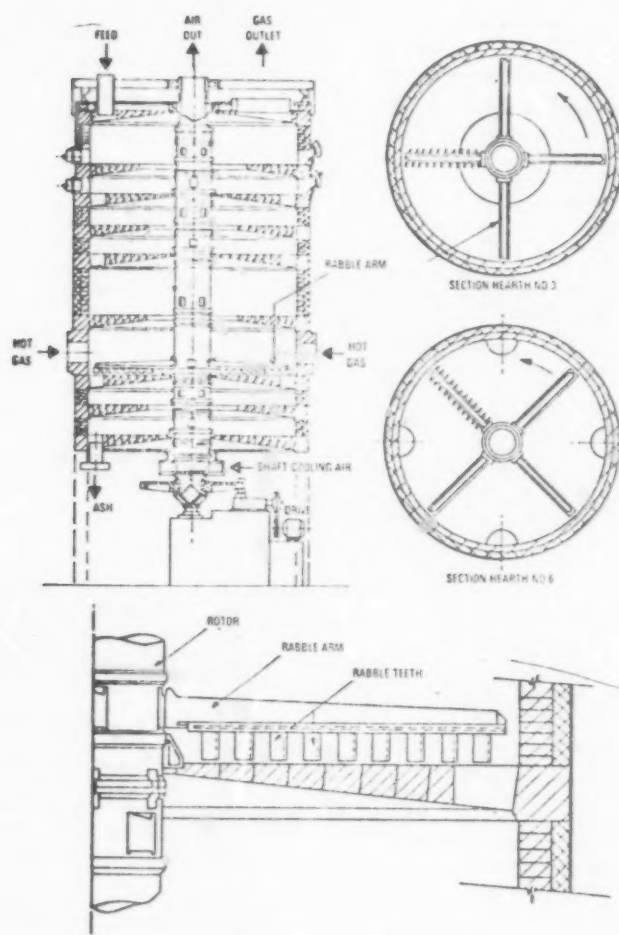


Fig. 4. Multiple-hearth furnace

PROCESS INSTRUMENTATION

I INTRODUCTION

The purpose of this presentation is to acquaint the trainee with some of the instruments that are available today for possible on-line applications to conventional sewage treatment processes and to describe briefly how they work. Finally, a few instruments which are in advanced stages of development will be touched on.

II ON-LINE INSTRUMENTS

Figure 1 shows where some of these instruments have been or could be applied to a typical activated sludge plant. There are many other plant configurations which could be used and there are many other possible instrument applications. This diagram is for

illustrative purposes only. It is not intended to show the best or recommended way of doing any of these things. Where pieces of equipment are identified by brand name, manufacturer, or sketch, no endorsement is implied. Usually, similar instruments are available from several manufacturers.

In the detailed descriptions which follow, these instruments are in the same numerical order that is shown on this schematic diagram. Where only a signal line is shown running from a sensor to an instrument, the output is only a meter reading or a chart record. Where a control signal line is shown running from the instrument to some other component, such as a valve or motor, a process control function is indicated.

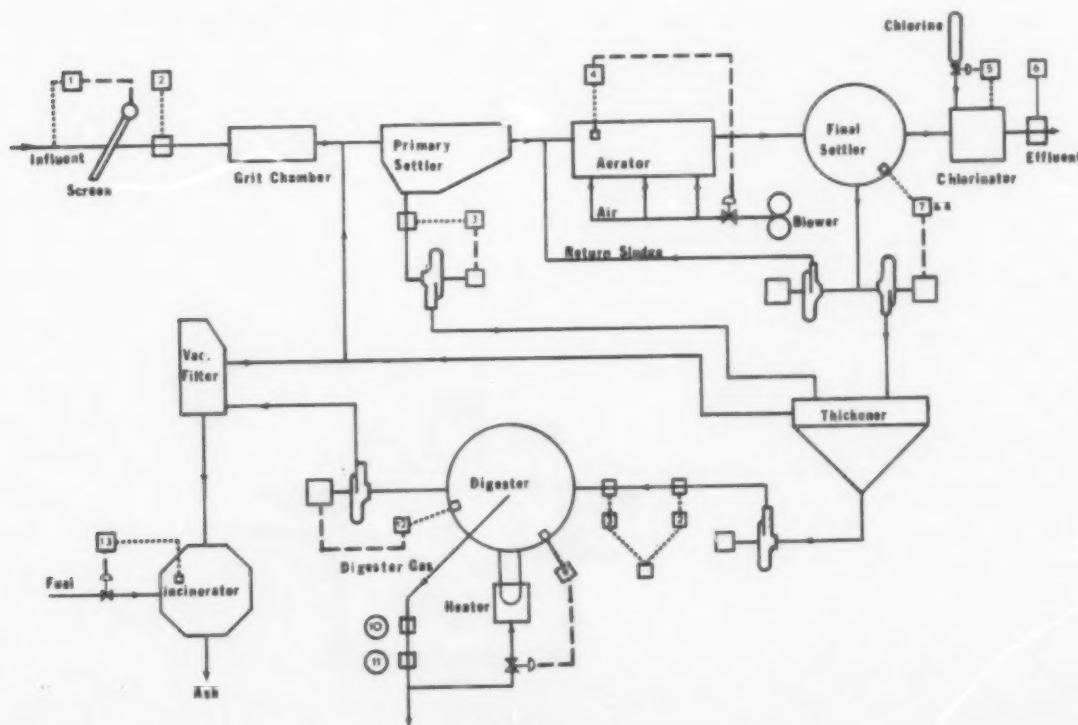


FIG. 1

III INDIVIDUAL INSTRUMENTS AND CONTROLS

A Bar Screen Control (Figure 2)

This device measures the differential level upstream and downstream of the bar screen by bubbling air through tubes immersed in the flowing sewage and measuring the back pressure created by these levels. This differential can be

read out or recorded directly in inches of water loss across the bar screen. The cleaning mechanism on the screen can be automatically actuated when this loss exceeds some present value. Additional electrical contacts can be provided to actuate alarms when unusually high head losses occur.

Such a device will cost from \$500 to \$600. One manufacturer is the Foxboro Company.

BAR SCREEN CONTROL

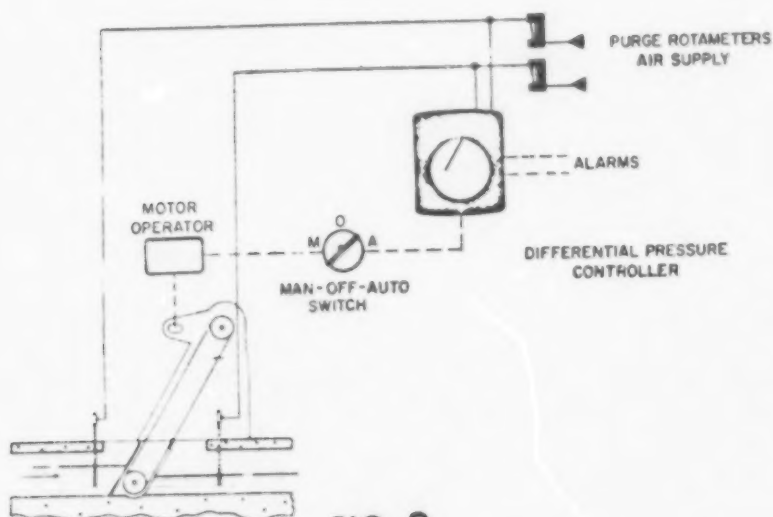


FIG. 2

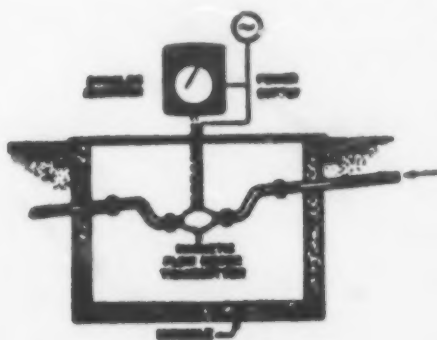


FIG. 3

B Raw Sewage Flow (Figure 3)

There are a number of ways to measure liquid flow, including flumes, venturi meters, orifice plates and magnetic flow meters. This figure illustrates the magnetic flow meter which is well suited to this application since it does not require any pressure taps and is unaffected by entrained solids or trash. It will work on pressure or gravity lines; the only requirement being that the line is completely filled with sewage at the point of measurement.

The meter works on the principle of electro magnetic induction which says that a conductor moving at right angles to a magnetic field generates a voltage directly proportional to the velocity of the conductor. The meter is made up of a transmitter and a receiver (recorder or indicator). The transmitter consists of a length of non-magnetic pipe, a section of which is enclosed by electromagnet. Two metallic electrodes, directly opposite each other and flush with the inside of the pipe, detect the low-level voltage signal generated by the moving sewage. This signal is transmitted to the receiver where it is read or recorded on a uniform scale. Minimum full-scale velocity is about 2.5 feet per second. Maximum velocity is usually limited by hydraulic considerations. Such meters are sold by Fischer and Porter, and by Foxboro. Prices depend upon pipe

size, with a 6" meter and recorder costing about \$3,000.

C Primary Sludge Density Meter (Figure 4)

The benefits derived from pumping thick sludge are obvious and several methods are used to control the density of pumped primary sludge. In small plants the sludge is often visually observed, while in larger plants programmed timers are used. Another method is the use of a sludge density meter which will provide continuous density analysis and pumping control.

These meters consist of a Source Head, a Detector Unit, and an Amplifier. The source head and the detector are mounted opposite each other on the sludge piping. The source head contains a quantity of some radioisotope such as Cesium-137. Gamma rays from this source pass through the pipe, through the sludge where they are absorbed in proportion to the density or percent solids, and into the detector unit. The rays reaching the detector produce a current which is inversely proportional to the sludge density. This current is amplified in the amplifier and passed on to a measuring instrument and controller where the results can be read directly in density units.

At present these meters are recommended only for primary sludge. Prices vary with

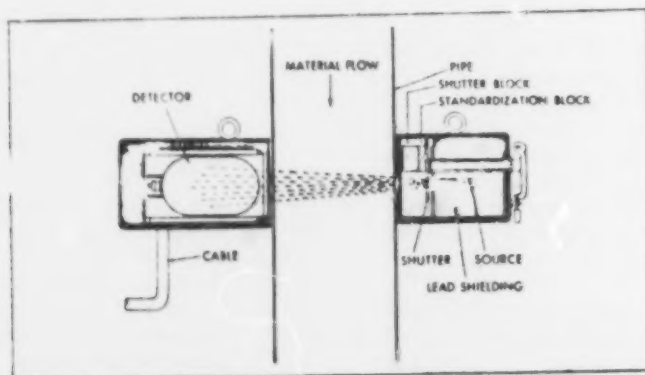
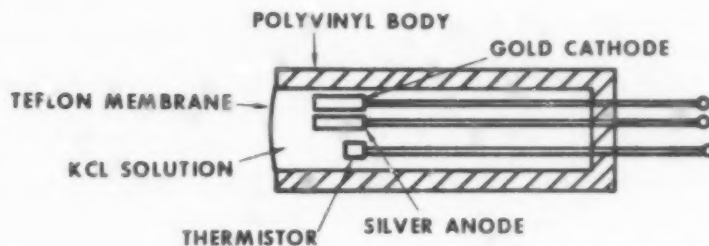


FIG. 4



DISSOLVED OXYGEN SENSOR

FIG. 5

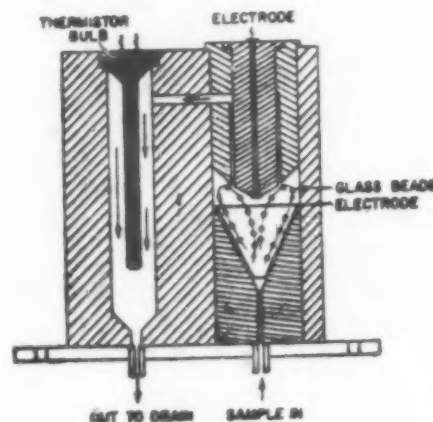
pipe size, but will run about \$4,000 for a 6' line. Three manufacturers are: Industrial Nucleonics, Ohmart and Nuclear-Chicago.

D Dissolved Oxygen Meter (Figure 5)

One of the quantities which is of interest in the activated sludge process is the level of dissolved oxygen in the mixed liquor in the aerator. Since the cost of aeration is the largest single cost in the activated sludge process, automatic control of the DO level could result in a significant cost reduction.

There are several different brands of DO meters available which use a polarographic electrode for a sensor. Oxygen is reduced at the cathode surface causing a current to flow which is proportional to the partial pressure of oxygen in the liquid being tested. This current signal is then fed into an amplifier, the output of which can be used to drive recording or control devices.

Several different pairs of metals are used for the sensor depending on the manufacturer. Two of these are, silver anode and gold cathode, lead anode and platinum cathode. In some instruments the electrodes are separated from the sample by a thin Teflon



CELL DETAILS

FIG. 6

membrane, which is permeable to gases. When this construction is used, a supporting electrolyte such as potassium chloride is used. These instruments are available for portable use and fixed installations. They are sold by Bechman, Fairchild, Robertshaw, Union Carbide, and Weston and Stack. Those for fixed installation cost about \$1,400.

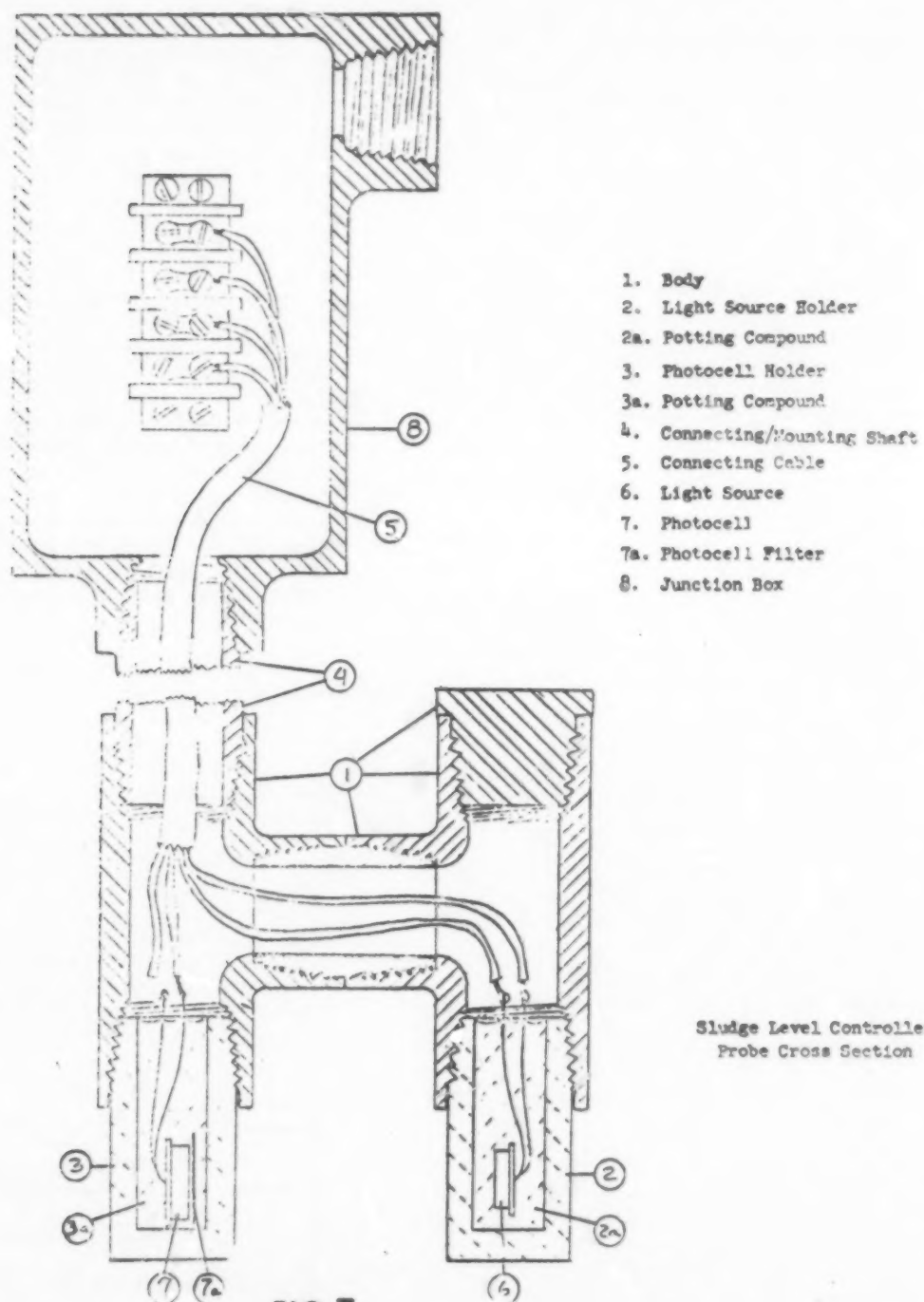


FIG. 7

176

E Chlorine Residual (Figure 6)

This is a schematic drawing of a Free Residual Chlorine Analyzer Cell made by Foxboro. The center electrode is platinum and the outer electrode is copper. The glass beads are used to keep the electrodes clean. The sample stream enters the electrode chamber where a voltage is generated by the fluid across the electrodes. The sample then passes to the adjacent chamber where it contacts a thermistor which provides temperature compensation. The electrical signal can then be used to operate a recorder or control a chlorinator. For satisfactory operation, the pH should be between 6 and 8.

This instrument, with a controller, costs about \$2,300.

F Turbidity Meter

The clarity of the effluent can be measured as turbidity. Three manufacturers that make turbidity measuring instruments are Beckman, Foxboro and Union Carbide. All three of these use a light source and measure either transmitted light, scattered light or reflected light. For example, the Union Carbide meter uses a lamp, the beam of which is split at right angles and directed toward two photo conductive cells. The path to one cell is about 1-1/2 times as long as the other. The longest path is a little less than 1". This unequal path length is used to compensate for dirt on the detector windows. As one detector sees a decrease in light due to either dirt buildup or turbidity, it causes an increase in lamp voltage to bring the signal back to its initial strength. The difference between the signals from the two detectors is then read as turbidity. Prices for these meters range from about \$1,400 to \$2,000.

G Sludge Blanket

Two instruments which are quite different, but yet provide the same information, are shown in Figures 7 and 8. Neither one will indicate what the sludge level is at any given time, but both are intended to detect the sludge level when it reaches some predetermined point.

The first (Figure 7) is the American Bowser Corporation Sludge Level Probe. It is intended for use with a timing device and sensitivity selector to control sludge pumping. The components of the probe are identified in the illustration. One feature, which is not shown, is that the light source is a light emitting diode which is immune to shock and permits the use of a filter to restrict the response to sunlight. A timer is used in conjunction with the probe to prevent frequent on-off operations of the pump. This probe, together with the necessary power supply, relays, timer, etc., costs about \$1,200.

The second sludge blanket level instrument is shown in Figure 8. This is the Sensall Interface Sensor, manufactured by the National Sonics Corporation. The sensor consists of two piezoelectric crystals separated by the transmitter crystal, directed through the liquid and picked up by the receiver crystal and then amplified by the control unit.

The sensor may be used either in a reflection mode or attenuation mode. To operate in a reflection mode, it must be mounted about 10° to the horizontal as shown here. When the ultrasonic signal passes the interface, most of the signal is reflected and refracted so that only a small amount reaches the receiver. If the interface is not between the two crystals, the greater part of the signal will reach the receiver.

Usually liquids with entrained solids have more sonic attenuation than clear liquids. If the attenuation of the sludge is sufficiently greater than that of the liquid above it, the attenuation mode can be used to determine

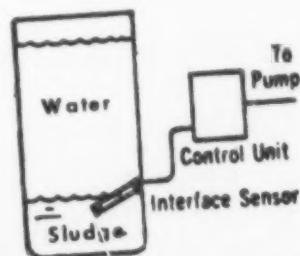
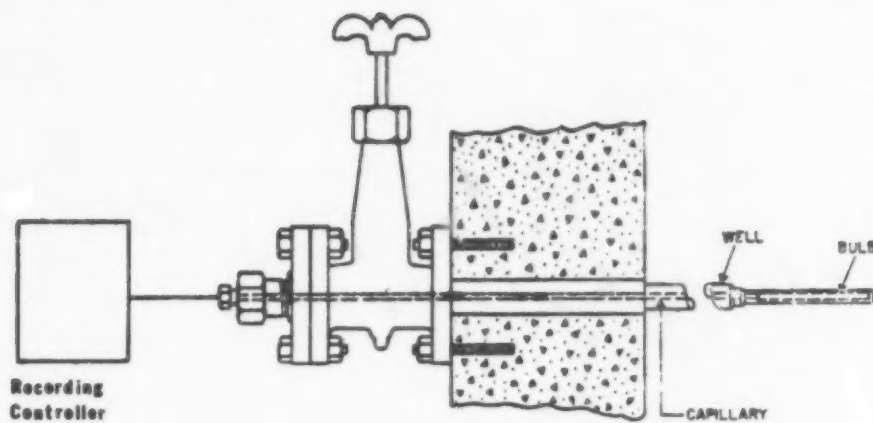


FIG. 8



Thermometer Well and Bulb

FIG. 9

the type of liquid present at the sensor. However, this mode of operation is not recommended for sewage sludge.

This sensor together with the control unit sells for about \$350.

H Mass Flow of Sludge

Measuring and recording of mass flow of sludge to the digester, may be accomplished by electronically combining the output signals from a magnetic flow meter and a sludge density meter and feeding the resultant signal into a recorder. The magnetic flow meter and sludge density meters would be essentially the same as those described above for measuring raw sewage flow and primary sludge density. The manufacturers of either the flow meters or density meters will assemble the meters, the recorder, and the necessary electronics for about \$10,000.

I Digester Temperature (Figure 9)

Probably the most familiar application of automatic control is that of digester temperature. These instruments are available from a number of manufacturers. This

one shown here consists of a sensing element in a protective well with a capillary tube leading to the recording controller. The signal from the controller to the fuel control valve can be either pneumatic or electric. Often the temperature controller will be integrated with the burner and will be separated from the recording function.

An instrument for local recording and control of digester temperature will cost around \$700.

J Digester Gas Flow (Figure 10)

Since the quantity of gas produced by a sludge digester is a good index of digester efficiency, it may be desirable to measure and record gas production rate. This can be done with several different types of meters, including a simple orifice plate meter as shown here. The pressure differential across the orifice plate is transmitted for remote reading. Such meters are available from Foxboro, Meriam, and others. The cost is about \$400.

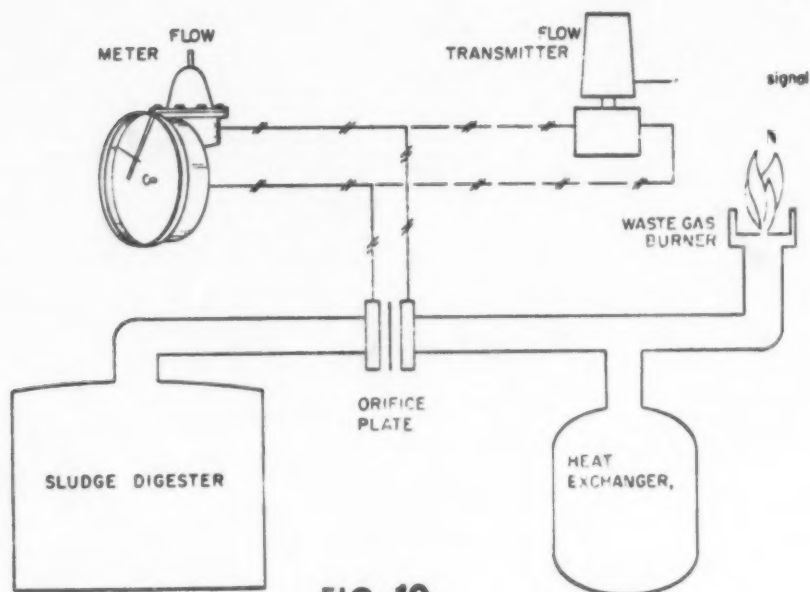
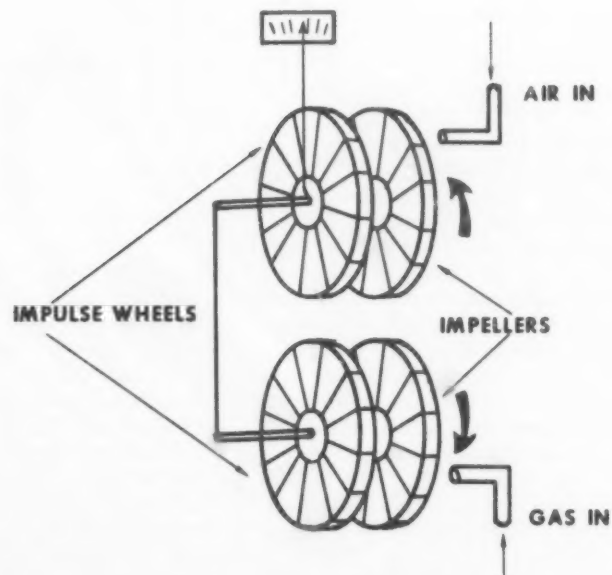


FIG. 10



RANAREX INDICATOR

FIG. 11

K Digester Gas Analysis (Figure 11)

Typically, digester gas is about 65% methane and 35% carbon dioxide. Problems with digestion may be signaled by a sudden rise in CO_2 before total gas production falls off. Therefore, it may be desirable to monitor the CO_2 content of digester gas.

There are a number of ways to measure CO_2 , among which is the unique instrument shown here. It is called Ranarex and is made by the Ranarex Department of the Permutit Company. It is a mechanical device which actually measures the specific gravity of the gas. It will, therefore, provide analysis of a two-phase gas system. The figure shows the operating principle. The instrument consists of two hollow cylindrical chambers each of which contains a motor-driven impeller and an impulse wheel. The lower impeller draws in a continuous sample of gas and discharges it against the vanes of the companion impulse wheel creating a torque proportional to the density of the gas.

Similarly the upper impeller draws in a continuous sample of ambient air and discharges it at the same speed, but in opposite direction to the gas creating an opposing torque proportional to air density. The difference between the opposing torques is a measure of the specific gravity and is transmitted through impulse wheel pivot shafts to a pointer and a recording chart pen.

There are a few conditions which must be met. The gas should be essentially at atmospheric pressure and ambient temperature and both gas and air should have the same humidity. This last condition is easily met by saturating the air in a built-in humidifier. Some advantages claimed for this instrument are rapid response, rugged construction, simplicity, and low installation cost. The price including recorder is about \$1,200.

L Digester Level (Figure 12)

Accurate knowledge of liquid level is essential in digester operation. The

DIGESTER LEVEL MEASUREMENT PNEUMATIC

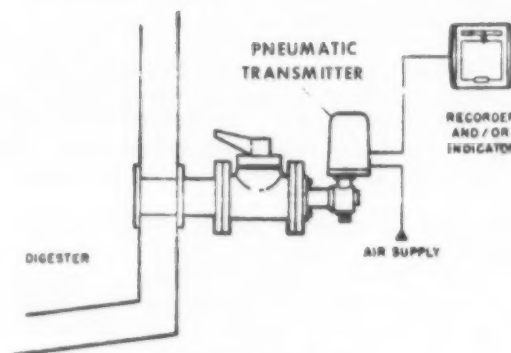


FIG.12

instrument shown here will permit remote reading or recording of that level. This particular instrument operates by balancing an air pressure on one side of a diaphragm against the pressure of the digester liquid on the other side. By pneumatic transmission the level signal may be used to indicate or record digester level or to sound alarms. To facilitate service, a valve is installed between the digester and the instrument. These instruments are available from Foxboro and other manufacturers. With a recorder, they cost about \$600.

M Incinerator Temperature

Incinerator temperature must be controlled to insure destruction of the sludge without exceeding safe upper limits with resultant damage to brickwork and other incinerator parts. Such controls are usually integrated with the burners and are often supplied with incinerators. Two manufacturers of temperature controlled burners are Eclipse Fuel Engineering and North American Manufacturing.

IV NEW INSTRUMENTS

There are several instruments of interest, which are not shown on the flow diagram (Figure 1). Some have only recently been put into production.

Figure 13 shows the Arthur Respirometer now called the Biomand I by the manufacturer, Phipps and Bird, Inc. This instrument will measure oxygen demand in wastewater. The schematic shows the principle of operation.

The sample is introduced manually and the automatic cycle started. When the cycle begins, the vent solenoid (6) opens, venting the system, allowing the manometer fluid to equalize and the recorder pen to return to the base line. The drain solenoid (1) opens, allowing the sample chamber to drain. The pumps (2) (12) stop at the end of the drain cycle. The drain solenoid closes and the fill solenoid (3) opens, allowing the sample to enter the sample chamber. The fill solenoid closes, the pumps restart, and the system vent closes.

As the available oxygen is used, the pressure drop in the closed system (7) allows the manometer fluid to flow from the open side. As the float (8) which is attached to a transducer (9) drops, a signal is sent to the recorder (10) which reads directly in milliliters of oxygen demand. It is claimed that a procedure which takes about four hours gives results which can be correlated with a 5-day BOD for a particular wastewater. This instrument costs about \$7,500.

Figure 14 is a schematic diagram of the "Continuous TOC Monitor" made by Automated Environmental Systems, Inc. It is intended for continuous on-line operation and comes equipped with either an on-line blender or on-line filter. The method of operation can be seen from this diagram. A constant head tank provides a continuous sample of the water to be analyzed. From this tank the water enters the top of the nitrogen sparge column where it is treated with hydrochloric acid to maintain a pH of about 3. The sparge column, essentially a counter-current gas stripper, removes CO_2

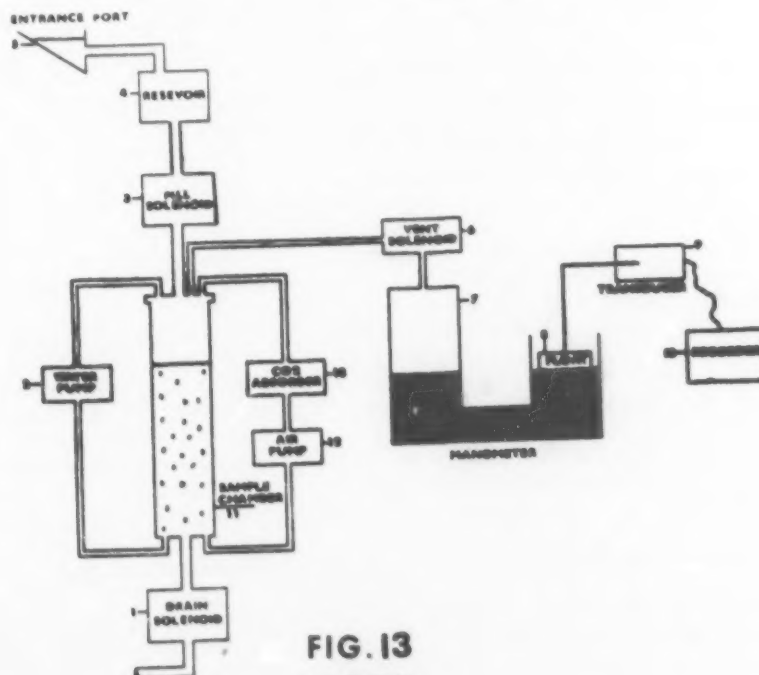
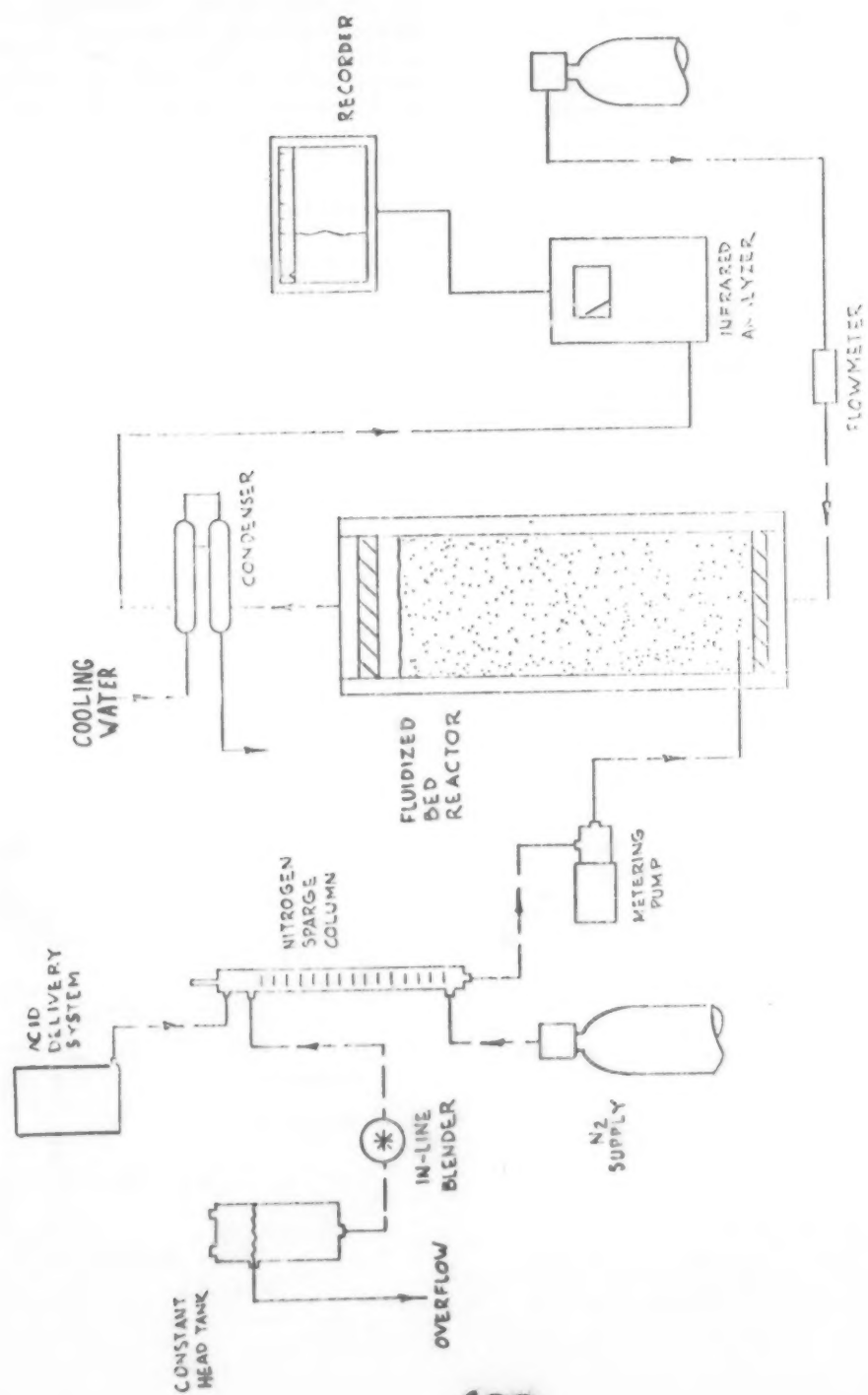


FIG. 13



CONTINUOUS TOC MONITOR — FLOW DIAGRAM
FIG. 14

from the acidified sample, yielding an effluent free of inorganic carbon.

The carbon-free sample is then metered into a fluidized bed reactor by a metering pump. The bed temperature is 850°C. Oxygen is supplied at ten times the stoichiometric requirement to oxidize the maximum amount of TOC which may be present. The oxygen and the vaporized sample provide the gas for fluidization of the bed. In the reactor, organic carbon in the sample is oxidized to carbon dioxide. The reactor's effluent is a gas stream of water, CO₂ and O₂, plus oxidation products of other non-carbonaceous compounds present in the water sample. A condenser cools the gas stream to less than 50°C.

The CO₂ in the gas stream is measured by a non-dispersive infrared analyzer. The measured CO₂ is proportional to the Total Organic Carbon in the water sample. The price of this instrument is expected to be about \$8,500.

Figure 15 is a flow diagram of the "Process Carbonaceous Analyzer" made by Beckman. This is another automated "on-stream" instrument that employs the combustion/infrared method of carbon analysis. However, it differs from the preceding instrument in a significant way. The principle of operation is shown in this schematic drawing. Water from the sample source flows continuously through a 20 microliter hole in the slider insert of the valve. At intervals of from 2 to 5 minutes the slider operates to transfer this measured sample into an air carrier stream. The air carrier injects the sample into a catalytic combustion furnace maintained at 950°C. Here the water is vaporized and the carbonaceous material is oxidized to carbon dioxide. The air stream then carries the steam and CO₂ out of the furnace where the steam is condensed and removed. The CO₂ is measured in a non-dispersive infrared analyzer. The important difference between this and the preceding instrument is that this one also measures

the inorganic carbon in the sample. Another difference is that with this instrument, it is recommended that the sample be filtered because the tolerance for solids has not yet been established. The price of this instrument is about \$9,200.

Another similar instrument is Union Carbide Corporation's "Total Carbon Analyzer" shown schematically in Figure 16. It is quite similar to the preceding instrument, except that an inert gas, nitrogen, is used as the carrier gas. The sample can be injected manually or the instrument will work automatically for 24 hours.

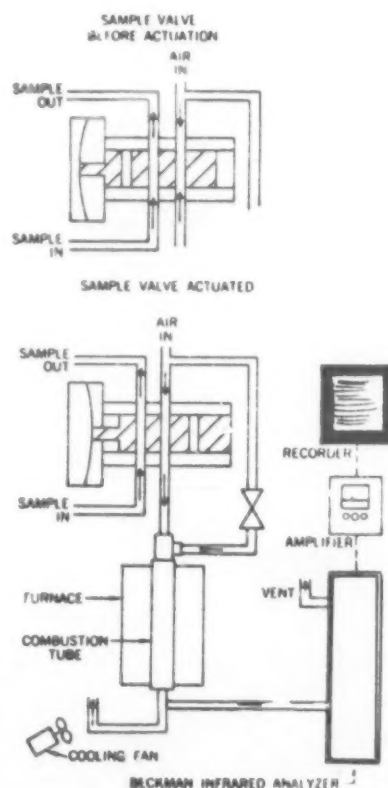


FIG. 15

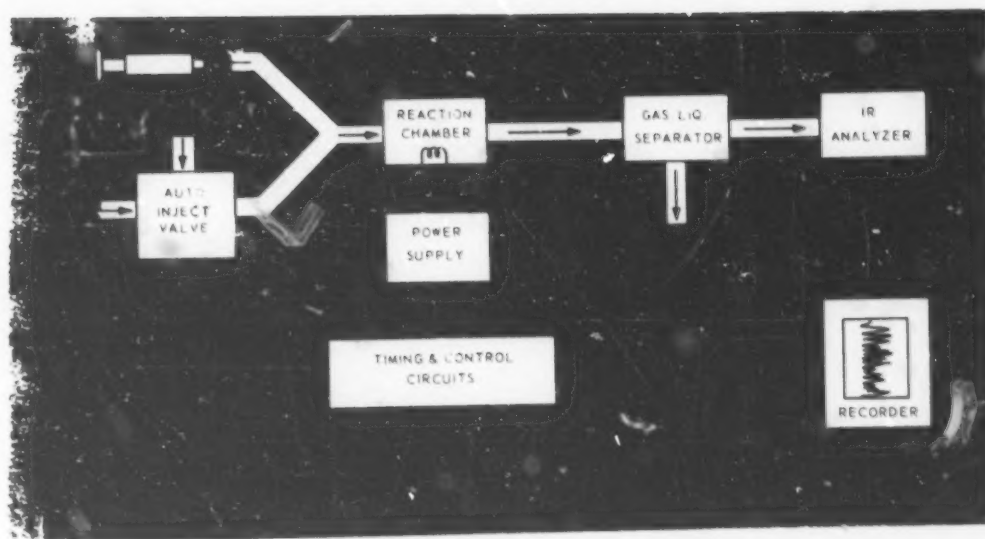


FIG. 16

This outline was prepared by W. McMichael, Mechanical Engineer, Advanced Waste Treatment Laboratory, OWP, EPA, Cincinnati, OH 45226.

SECTION IV

Solids disposal, personnel training, safety, maintenance, and performance control practices are recurrent facilities management problems. Current developments are considered relative to operational problems.

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ULTIMATE DISPOSAL TO THE ENVIRONMENT

I INTRODUCTION

A Pollutants removed from wastewaters must be treated in such a way that they will not pollute the environment.

- 1 A pollutant is a substance that interferes with the intended use of the environment.
- 2 Incineration to reduce volume of organic wastes must not lead to air pollution.
- 3 Likewise, the effluent from a scrubber used to control air pollution from a furnace must be treated to prevent water pollution.
- 4 Only three places to put polluting substances. Air, land, ocean. Not in surface waters.
- 5 Pollutant substances must be rendered innocuous either by dilution below background level or by locking up in precipitates.

B Ocean Disposal

- 1 Barge to deep water and sink to bottom. Lock up on bottom.
- 2 Ocean pipeline to deep water and sink solids. Dilute and lock up. West Coast.
- 3 Ocean diffuser into well mixed area. Dilute, Gulf and East Coast Continental Shelf.
- 4 Food chains may concentrate poisons killing larger species.

C Land Disposal. Fill.

- 1 Not suitable for soluble substances such as salts.
- 2 Needs dewatering to produce solid that will bear a load. Useful for insoluble inorganic wastes.

- 3 Organics will putrefy and decay and may produce foul seepage and subsidence of the surface.

D Land Disposal. Surface.

- 1 Not suitable for solubles except nutrients in quantities utilized by plants.
- 2 Low cost dewatering; can handle liquid sludges.
- 3 Low cost oxidation of organic matter.
- 4 Many elements locked up on soil minerals.
- 5 Improves soil for agriculture and forestry.
- 6 Chicago planning long pipeline to carry sludge to waste lands.

E Land Disposal. Wells.

- 1 Wells into porous formations are unsuitable for sludges or liquids containing filterable solids.
- 2 Useful for salt disposal into saline aquifers.
- 3 May leak out and contaminate other waters.
- 4 Large volumes may produce earthquakes and land movement.

F Polluting Substances

Consider pollutants on an element-by-element basis. Fortunately do not have 101 problems as most elements will not be pollutants.

II ORGANIC SUBSTANCES

A Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Sulfur, Ash.

B Principal problem in disposal of organic sludges is water. Twenty to fifty times as much water as all other substances in waste.

C Carbon and hydrogen in organic compounds can be oxidized to CO_2 and H_2O which do not pollute the atmosphere. Avoid CO and odor by proper furnace operation.

D Heat Production:

1 Oxidation of 1 lb. of organic sludges is sufficient to evaporate about 2 lb. of water. Up to 3 lb. for oily sludge since combined O as in carbohydrates reduces heating value.

2 High temperature oxidation uses all the heat of combustion to evaporate water left in the sludge and usually requires excess fuel.

3 Economics of incineration are therefore closely tied to dewatering by sedimentation, filtration, and drying.

E Treatment of wet sludge to aid further processing.

1 Anaerobic digestion. Reduces solids about 50% by hydrolysis and fermentation to methane gas which is burned to CO_2 and water. Produces foul supernatant liquor which returns organics and nutrients to the plant for recycle.

2 Sludge cooking at 370° F. Porcous Process improves filterability of solids. Returns 10-20% of the BOD and 60-80% of the nitrogen.

3 Wet oxidation - Zimpro at 350° F removes 15% of COD by oxidation; dissolves 25% of solids and 90% of nitrogen. Higher temperatures destroy more solids. Improves filtration, produces a foul supernatant liquor.

4 Aerobic digestion. Aerate for 1-30 days. Stabilizes solids, retains nutrients but does not aid dewatering.

F Oxidation and dewatering on land surfaces. An "old-fashioned" process.

1 Organics are oxidized by soil bacteria.

2 Nutrients and other pollutants are fixed to a significant extent and kept out of water supplies.

3 Must control putrefaction and spread of pathogens by pretreatment.

III PHOSPHORUS

A Composition and Occurrence

1 Sewage contains orthophosphate, polyphosphate and organic phosphates. Total P in secondary effluent averages near 8 mg/l as P (24 as PO_4 , 18 as P_2O_5), large fluctuations with place and time.

2 Biological treatment, which may begin in the sewers, hydrolyzes about 90% of the phosphates to ortho- as HPO_4^{2-} in secondary effluent.

B Organic sludges carry a fraction of the total P load.

1 Anaerobic digestion normally returns a large fraction of the P to the plant.

2 Combustion retains P in ash.

3 Land spreading fixes P on soil minerals but silt carries P into streams.

C Lime Sludges

1 High pH precipitates calcium phosphate from secondary effluent as $\text{Ca}_5(\text{OH})(\text{PO}_4)_3$, hydroxyapatite. This is frequently referred to and calculated as tri-calcium phosphate or "tri cal," $\text{Ca}_3(\text{PO}_4)_2$, which is called bone phosphate of lime, bpl, in Rock Phosphate analyses.

2 Lime dosage of up to 600 mg/l as $\text{Ca}(\text{OH})_2$, (450 as CaO) has been used to raise pH above 11 and precipitate calcium phosphate.

- 3 Also precipitates alkalinity as CaCO_3 and gelatinous Mg(OH)_2 which traps the turbidity, mostly organic.
- 4 Mg(OH)_2 can be dissolved by CO_2 without significant loss of lime at pH 9.5. Slight excess of CO_2 may be used to stabilize sludge against scale formation.
- 5 Lime sludge can be dewatered easily by sedimentation and vacuum filtration or centrifugation to 25-40% solids.
- 6 Burning in a lime kiln or incinerator converts CaCO_3 to CaO . Calcium phosphate is essentially unchanged.
- 7 CaO can be slaked to Ca(OH)_2 which can be reused. Calcium phosphate remains with inerts including MgO which does not slake.
- 8 High phosphate sludge has low solubility in water and can be safely dumped. May have market value as fertilizer since P is available to growing plants.
- 9 Recovered lime costs nearly as much as new lime but partially solves disposal problem.
- 10 Lake Tahoe, California

D Alum Sludges

- 1 Aluminum salts hydrolyze to aluminum hydroxide and precipitate phosphates.
- 2 Optimum pH near neutrality.
- 3 Either alum, $\text{Al}_2(\text{SO}_4)_3 \cdot \text{XH}_2\text{O}$, or sodium aluminate, NaAl(OH)_4 , can be used with suitable pH adjustment.
- 4 Aluminum to phosphate ratio close to 2:1. $\text{AlPO}_4 \cdot \text{Al(OH)}_3$ probably not a pure compound.
- 5 Aluminum phosphate can be dissolved at high pH (11-12) liberating aluminate Al(OH)_4^- . If calcium is present calcium phosphate will precipitate.

- 6 Reuse of aluminate requires acid to bring down pH. May supply acid as alum also providing makeup aluminum. Some dragout of insoluble aluminum precipitate expected.
- 7 Disposal of aluminum hydroxide sludges rich in organic matter may be difficult. Aluminum hydroxide clogs soil and won't dewater unless frozen. Aluminum phosphates are not dissolved in anaerobic digesters.

E Iron Salts

- 1 Hydrolyze to produce ferric hydroxide Fe(OH)_3 which removes phosphates as basic ferric phosphate.
- 2 Ferric phosphate FePO_4 reduced in digesters to ferrous phosphate $\text{Fe}_2(\text{PO}_4)_3$. Insoluble but dissociated by H_2S to form FeS liberating soluble phosphates.
- 3 Possible utility when acid mine wastes or iron pickle liquor is available. No recovery.

IV NITROGEN

- A All nitrogen comes from the air and ultimately returns to the air.

- 1 All forms of N are biologically interconvertible. Report all forms of nitrogen as mg/l N.
- 2 All except N_2 are pollutants. "Good" fertilizers on the land but "bad" fertilizers in water.

B Organic Nitrogen

- 1 Burn to N_2 gas with some oxides of nitrogen if furnace design is inadequate.
- 2 Hydrolyze to NH_3 by anaerobic or short time aerobic treatment.
- 3 Oxidize to nitrate with long time aeration in presence of suitable bacteria.

C Ammonia

- 1 Pollutant above 1 mg/l in municipal or surface waters.
- 2 Chlorine destroys ammonia producing N_2 but requires 10 parts of Cl_2 per part of NH_3 -N.
- 3 Ammonia present mostly as ammonium ion below pH 9 mostly as dissolved NH_3 above pH 10. Air strip with 300 cu ft. air/gal. water at pH 10.8.
- 4 Lake Tahoe will combine lime precipitation of phosphate at high pH with air stripping of ammonia.
- 5 Battelle-Northwest is testing a zeolite to concentrate ammonium in smaller volume of water. This will reduce size of air stripping tower. Air can then be used in furnace where NH_3 will burn to N_2 .
- 6 Soils adsorb NH_4^+ . Bacteria in soil convert excess to soluble nitrates. Growing plants need NH_4^+ or NO_3^- .

D. Nitrates

- 1 PHS limit 10 mg/l as N in drinking water. Causes "blue babies".
- 2 Algal nutrient in surface waters and source of dissolved oxygen in polluted waters.
- 3 Denitrified by growing bacteria at low oxygen levels supplying O_2 and liberating N_2 . Denitrification occurs in soils and can be done in packed beds or tanks if food such as methanol is supplied.

V SALTS IN SOLUTION

A Na^+ , K^+ , Ca^{++} , Mg^{++} , salts of Cl^- , HCO_3^- , SO_4^{--}

- 1 Soluble. No good precipitant.
- 2 No economical sale.

3 Illegal to discharge on surface in some arid areas including Texas.

4 Solar evaporation to solid to reduce transportation costs.

B Dilute in sea water or salt lakes.

1 Discharge to rivers on spring floods has been practiced.

C Inject into underground cavities or saline aquifers.

D Concentrated salts from Reverse Osmosis, Electrodialysis, Ion Exchange.

1 Scale forming if concentrated 10-fold, i.e., 90% water recovery.

VI TRACE ELEMENTS. POISONOUS IN EXCESS

A Lime clarification will remove Ca, Mg, Sr, Ba, Al, Cr^{+3} , Mn, Fe^{+3} , Co, Ni, Cu by precipitation. May also remove Zn, Cd, Hg, As, Sn, Sb, and Pb by adsorption.

B Hg, Cd, and Zn strongly adsorbed on organics but are volatile and may be lost in flue gases.

C Borates--from peroxyborate bleaches in heavy duty detergents and scouring powders.

1 Not serious for drinking water.

2 Max. 0.5 mg/l in irrigation water for fruit trees and some other plants.

3 May need ion exchange resin specific for borates.

D Chromates. CrO_4^{--} , $Cr_2O_7^{--}$ in acid solution.

1 From cooling water treated to reduce corrosion and from electroplating.

2 Reduce to Cr^{+3} with SO_2 and precipitate as $Cr(OH)_3$.

E Cyanides. CN^- from electroplating.

1 Oxidize to CO_2 , N_2 with Cl_2 .

F Heavy Metals, Cyanides, Selenium, Arsenic, and some other poisons can be kept out of wastewater more economically than they can be removed.

A portion of this material has been published in the Proceedings Tenth Sanitary Engineering Conference, Department of Civil Engineering, University of Illinois, Edited by J. H. Austin and Ursula Weise, May 1968.

This outline was prepared by Dr. Robert B. Dean, Chief, Ultimate Disposal Research Activities, Division of Research, Advanced Waste Treatment Research Laboratory, Cincinnati, OH 45226.

TRAINING FOR WASTEWATER TREATMENT PLANT OPERATORS

I INTRODUCTION

- A The 1968 inventory of municipal waste facilities (1) estimated that 70 million people of 197 million population were connected to sewage systems. Some type of treatment was provided for 93% of the connected population of which 65.7% was of the secondary type. During the six years since the 1962 inventory, secondary plant facilities had increased by 51% and the population served by 40%. The 1968 report lists 12,565 treatment plants for 12,911 communities. Facilities are being provided at an increasing rate. These plants stress secondary and/or advanced treatment operations as necessary to upgrade effluent quality. The operations may be expected to increase in complexity as more people are connected and as treatment requirements increase.
- B The report on Manpower and Training needs (2) states "Still it is always the skill of the people which transforms inanimate buildings and machines into productive devices."
- 1 Operating personnel for existing treatment facilities perform remarkably well in many cases. However, most existing facilities are not functioning as well as they could because of public indifference after the plant is built and because operating personnel commonly lack training adequate for their responsibilities.
 - 2 The community is committed to debt service and default penalties. Operating funds are not so protected. Consequently, economy starts at the operating level. The facility cannot serve its intended function with a budget too low to attract and hold competent trained personnel with adequate funds for materials, maintenance and repair.

- C Operators are difficult to classify. The operator in charge is responsible for all phases of the facility. The shift operator in a large plant may be responsible for a limited assignment such as grit and trash facilities. The small plant operator has a difficult assignment because he may have little backup support, must perform all functions and frequently has had little training for it. Overall functions in operation include:
- 1 Inspection, housekeeping, meter reading, adjustments, lubrication, repair, reports of events and calculations involving performance and costs.
 - 2 Control of physical operations such as screening, grinding, pumping, clarification, aeration, filtration, drying, etc.
 - 3 Control of biological conditions favoring desired performance for aerobic, anaerobic or facultative working organisms under varying loading and conditions.
 - 4 Control of chemical processes such as neutralization coagulation oxidation disinfection.
 - 5 Perform sampling and testing operations indicating work done or remaining to be done.
 - 6 Serve as an information source for public officials, lay groups, suppliers, consultants on specific facility problems.
- D Technology is available today to clean our environment if we accept performance as the main criteria rather than cheapness. Institutions are available for planning, construction, and operation. Facilities are in short supply. Trained qualified

people are in shorter supply at all levels of environmental technology.

E Environmental technology involves many functional groups such as planning survey, management, consultation, design, supply, construction, maintenance and operation.

- 1 Training in the last group has tended to be of the unplanned hit or miss category. On-the-job training depends on the co-workers attitude and has tended to be spotty and slow without planned training with rotated assignments.
- 2 Training must be suited for student capability and background. The specialist may be trained by abstracts and theory, the intermediate level operator by cause and effect examples, entry level personnel may not even know the terms for questioning.
- 3 Operator training stress is increasing toward defining a job or task, designing instruction for the task and student background, and training personnel to fit the description. To work effectively, the definer, the instructor, and the student must communicate in common language.
- 4 Participant diversity in a given course should not be so large that the entry level student doesn't know the instructor's language, the intermediate level student can digest half of it and the advanced student is bored from the start. Some diversity is beneficial so that students participate as instructors on familiar topics.

F Each individual seeking to improve himself must make do-it-yourself training a way of life. Alertness during day to day contacts is the most valuable learning asset. Daily contacts include:

- 1 Trial and error or cause and effect relationships. This is commonly called experience.
- 2 Talk with available supervisors - interest in their problems is likely to reveal an amazing return interest.

3 Communicate with co-workers, on site and nearby. It's likely that each has a different response to a given situation; each has a "bit" to contribute.

4 Talk with local officials, manufacturers or supplier representatives, laymen, teachers - anyone who may be, or can be interested in wastewater treatment operation.

5 Each facility have some training plan - buddy system, counselor, rotating assignment, question and answer, topic development, reading program, on or off-site courses, practice sessions, or combinations thereof. Encourage this by active participation in them during group sessions or individual contact.

6 Become active in local, state and national association affairs in the field. Attend meetings where possible. Discuss personal impressions with others. Develop contacts with other operators, regulatory officials, instructors, industrial, consulting, and lay groups.

7 Develop ability to read with a purpose; use this ability regularly. Expand the plant and home library with periodicals, bulletins, texts, references, pertinent news items or releases. Include at least one good handbook and a dictionary. Set up a system of storage so that a given item can be found when you need it. Use the public, school, or trade library. Valuable source materials are available on a no charge basis from government agencies, schools, associations, and suppliers.

G It is necessary to remain unsatisfied with any given level of ability. It is not possible to maintain a static capability level. Any individual must improve or lose what is not used. Use the seven senses diligently - i.e. seeing, hearing, feeling, smelling, taste, common, and horse. Partial compensation is possible if you cannot use one or more of these; there is no compensation if you do not use available senses.

Enthusiasm is catching. It may not be possible to achieve all that enthusiasm attempted but no group action persists without enthusiasm.

- H Training to upgrade entry and intermediate level operating personnel to increase the number of qualified wastewater treatment plant operators is the major interest of this outline. Graduate and post graduate degree training, military inservice training with operating or environmental stress are very important to total environmental upgrading but may not be available for civilian personnel of the interest level intended. Time and space does not permit a complete listing. Selected examples are used to indicate current stress in training development.

II ACADEMIC TRAINING

- A It is estimated that our youngsters have had about 10,000 hrs. of TV time prior to primary school training. Activities in class, projects, educational TV, films, community, and lay groups increase awareness of environmental problems. Environmental consciousness may be spotty but it's popular to be an ecology "expert". Some of it is likely to register.

- B Secondary schools are the terminal academic level for a large segment of the population. Changes have been and are being made to adapt curricula to socioeconomic realities likely to be encountered. Environmental training is part of this.

- 1 More and more high schools are expanding present vocational training or are developing new programs at the junior and senior levels.
- 2 The Curriculum Activities Guide for Water Pollution Control and Environmental Studies prepared by The Tilton School, Tilton, NH (FWQA Grant 1TT1-WP-41-01) is another example of environmental activities at the secondary school level.

- 3 Many other forms of environmental emphasis are fostered by visual aids interests, commercial developers, text book publishers, trade associations, conservation or public interest lay groups and individual instructors or their associations.

- C Post High School Technician Training: Vocational training for the high school graduate has increased very rapidly in the past few years. Less than 20 vocational schools offered environmental training courses prior to 1968. A partial listing from the National Sanitation Foundation, Ann Arbor, MI, dated November 1970 included 70 post-secondary schools with environmental training in 23 states. Most of these are based upon two year curricula. It is not known how many of these are engaged in courses specific for water and wastewater.

- 1 These courses are intended to train technicians for job entry level capabilities in environmental operations.
- 2 The community college or vocational school is favorable for development of special courses for local development.
 - a The instructor staff may be a blend of professional teachers and working specialists.
 - b The course may include on-the-job training at appropriate points in the schedule.
 - c Liaison of academic and working knowledge provides a center of information on specific questions from local operators.
 - d Special topic seminars or short courses may be developed for evening or daytime sessions.

- D University courses traditionally have stressed theory and abstracts for planning, management, consulting construction, design regulation and related specialties.

Relatively small percentages of degree students have entered operations except in large or complex treatment facilities.

- 1 Undergraduate curricula have changed or are changing toward an interdisciplinary approach and process dynamics.
 - 2 Post graduate curricula are tending to be adapted more closely to student program interest than to rigid course schemes.
 - 3 Courses tend to be more closely related to total environmental interest than to an isolated segment of it.
 - 4 The Association of Professors of Sanitary Engineering have instituted several activities to encourage better student coordination with procedures outside of the university.
- E University non-resident training is unusually varied, such as:
- 1 Universities have been a source of materials, site of, and have provided instructors for many short term seminars, courses, or other training in conjunction with federal, state, industrial or professional groups.
 - 2 The Programmed Instruction Series for Water Pollution Control developed at the University of Michigan Center for Research and Learning by Drs. K.H. Mancy and L.A. Pursglove is a relatively new approach to self-study for operators.
 - 3 The Correspondence Course developed at Clemson University, Clemson, SC for South Carolina operator training, 2nd Ed., Dr. John H. Austin, Editor, is another form of operator instruction.
 - 4 The Seminar on Educational Systems for Operators of Water Pollutional Control Facilities sponsored by the U.S. Dept. of Interior, FWPCA and Clemson University at Atlanta, GA, November 1969 was important for orientation of past, present and future operator training considerations.

- 5 Sacramento State University, Sacramento, CA, Dr. Kenneth D. Kerri, Director, has prepared a correspondence course for operators that has input from both educators and operators. This project currently is in the finishing stages for printing.
- 6 Books, reports on special investigations, manuals, etc. have been prepared on special topics under sponsorship of contracting agencies.

III WATER POLLUTION CONTROL FEDERATION ACTIVITIES:

- A Advancement in the state of the art in all phases of water pollution control is the major charter commitment of the WPCF.
- 1 Publication of articles relating to planning, design, administration, research, and facilities operation, municipal and industrial, have been continued in the Federation Journal since its inception in 1928.
 - 2 The Manual of Practice Series have been prepared by member committees to reflect established practice and recommendations for special topics. MOP-1 considers safety practice, MOP-20 considers sludge dewatering. These are updated at intervals depending upon changes in stress or state of the art and upon committee activities.
 - 3 The WPCF acts in a liaison capacity among federal, interstate, state, university, industrial, and local agencies. It acts as an information source for agencies or individuals, professional associations and lay groups. As a professional association, it provides recommendations pertaining to proposed actions with an environmental impact.
 - a Model legislation on matters related to water pollution control organization, enforcement, certification and related regulations have been devised as guidelines for consideration by governing bodies and interested groups.

- b Suggested plans for organizing functional groups for implementation of WPC are available for use by public or corporate agencies.
 - c The WPCF serves with inter-professional associations such as the APHA, ASCE; AWWA and others on matters related to common interests such as design, standard methods, terminology.
- 4 The organization sponsors national, state, regional and local meetings, seminars or discussions of common interest to improve individual contacts and capabilities for working in a team effort.
- B Interest in operator status training and performance upgrading is a continuing objective. Recent trends have resulted in increased stress toward upgrading apprentice personnel and continued development of the operator who has not had the benefit of special training.
- 1 Mandatory certification of operator personnel has been a long term goal to increase status of personnel, continuity and performance of existing treatment operations. Uniform certification has not been realized but they have become more consistent and comprehensive. As of January 1, 1971, 27 states had mandatory certification, 20 had voluntary programs and 3 had no formal program. Mandatory certification is pending in several states.
 - 2 Training materials and programs have been formulated for two courses by committees of the WPCF to guide state, local, and other groups to provide improved training to upgrade personnel for operational capability. Strong emphasis on safety training earned a national safety award 1970.
 - 3 The Personnel Advancement Committee assembles data on existing certification, personnel training practice and provides guidance pertinent to new or developing programs.
- C A Workshop on Operator Training held at the Dallas meeting of the WPCF, October 1969, led to a new program emphasizing operator training needs and problems. Project "Manforce" has resulted from this effort. Manforce has assumed certain obligations of other activities of the WPCF, and parallels certain federal and state programs. It has a new organizational structure and limited staffing to date but certain factors are becoming evident to foster improved operator interest.
- 1 The "Deeds and Data" section of Highlights" is a new publication now appearing monthly that is written specifically for operators. It includes a sounding board for operators, information on operating safety, training questions, discussions, definitions and tips.
 - 2 A new committee for operator certification has been formed, Terry M. Regan, Chairman, Kentucky Certification Board, to enhance certification uniformity.
 - 3 The Black and Veatch report on operator and specialist job descriptions and staffing for wastewater treatment facilities has been reviewed by Personnel Advancement and Manforce Committees. Intent is to assist job classification and recommended staffing requirements for operations.
 - 4 A new staff member has been employed as Director of Education and Training.
 - 5 Top priority has been assigned to:
 - a Uniform certification
 - b Manpower needs and salary
 - c Recruitment and retention of capable operating personnel

IV STATE AND LOCAL OPERATOR TRAINING

Primary responsibilities for water quality, planning, development and implementation are state functions. Local agencies work within the state framework and regulations on front line functions of treatment technology.

A Certification authority and programs vary from state to state. An effective certification program requires a good entry level training program. This must be backed by effective recruitment, meaningful training and salaries adequate to hold trained personnel.

- 1 The common 1 to 5 day intensive training course at one year intervals at central locations continues to be useful for upgrading intermediate and advanced operator personnel. These groups have better contacts, usually can participate in monthly association or other meetings and have a better chance to continue their education by means not available to entry level personnel.
- 2 Entry level personnel usually require many more hours of training in terminology, equipment and task identification, practice, and basic arithmetical manipulations. This generally means that training must be brought to the recruit to minimize travel restrictions.
- 3 The states have power to certify and to enforce. Sometimes home rule or other limitations make it difficult to implement adequate staffing and budget allowances to attract and hold competent local personnel on a state-wide basis. Public relations and certification help.

B Entry level training has been expanded and is being offered at more sites. More expansion is needed. Instructors capable of productive training in treatment operation are difficult to locate - they generally must be developed and trained to present that which the apprentice needs in a manner understood by him.

- 1 The plant manager is becoming more conscious of personnel training responsibility. He may delegate training responsibility to others, but he is responsible for results.
- 2 Community colleges are becoming more numerous and more active as environmental training centers.
- 3 The public expects more; hopefully, they can be educated to the fact that environmental quality is not a free-ride. Service charges and other activities are moving in the direction of more realistic funding.
- 4 Local high school vocational training is improving. Use of the facilities for mixed academic and on-the-job training is expanding.
- 5 An increasing number of States have full time training directors, committees, and instructors for local training.
 - a Special training committees have been formed to contract for, receive money, and handle disbursements for training materials such as the Texas, California, New York, South Carolina and the Ohio training materials.
 - b Special state personnel have been designated for on site visits or group meetings for local training purposes.
 - c Support may be arranged for supplementary payment for local operator time devoted to training efforts.
 - d An increasing number of courses are becoming available where the participant receives combined class and on the job training (OJT).

V FEDERAL TRAINING ACTIVITIES

A The Federal Role in wastewater operator personnel training commonly is an

interagency function among federal, state or local governments, universities, corporations, associations or other contracting bodies. Financial support may be partial or complete through contracts grants or projects.

- 1 Objectives may include programs for staffing, curricula, manuals, visuals, lesson plans etc. to be used by others in class, home study, correspondence or other personnel training.
- 2 Financial support may be partial or complete for programs including instruction, materials, and administration by state or local agencies.
- 3 Joint federal, state or local input as agreed upon to fit the situation is common.
- 4 Direct federal training including funding, administration, supervision, instruction materials with or without student support may be provided.

B The office of Water Programs, EPA through the Division of Manpower and Training, State and Local Manpower Development Branch anticipates training approximately 2600 individuals in the next fiscal year. These programs are funded through the Department of Labor and the Department of Health, Education and Welfare as follows:

1 Institutional Training Program

Conducted at Community Colleges or Vocational Training Schools in nine states are presently planned (NY, MD, GA, OH, CA, MO, IA, TX, and ID). Two 22 week courses for 20 participants each include 440 hours of class instruction and an equal amount of time for practical experience in plant treatment. Approximately 360 enrollees will be trained for \$734,000 with trainee allowance of \$400,000. Instructors, supplies, equipment, administration, supervision and placement costs are included.

2 The Transition Training Program will be conducted at military installations with or near treatment plants and academic institutions (five locations now). Trainees at army bases will receive 240 hours of training, 640 hours at a marine base. Enrollees will be trained in groups of 12 including servicemen in their last 6 months of duty. Program cost is \$245,000 for instructors, supplies, equipment, supervision and placement of successful trainees. Students may qualify for Veterans Administration approved on the (OJT) additional training.

3 The coupled OJT National Projects will be conducted in 27 states with a total of 50 project sites. Each subcontractor is a unit of the state government, a municipality, a waste treatment district or community college. 70% of enrollees will be in skill improvement training, 30% at entry level. A total of 1000 individuals will be trained at a cost of \$1,260,000. Approximately \$300,000 will be used for instructors, supplies, equipment, administration and supervision.

4 The Public Careers Program is presently underway in VA, SC, TX (2 locations) WI and the Virgin Islands. Sponsors are charged with finding existing vacant positions and providing training at entry level as well as upgrading. Approximately 400 new and 500 upgraded individuals will be trained at a cost of \$1,500,000 of which \$1,200,000 will be for instruction, equipment, supplies and supportive services.

C The previous section represents a rapidly expanding ongoing program of federal, state and local activities.

- 1 Completed MDTA projects supported by the Depts. of Labor, HEW, Interior, and cooperating agencies in Indiana, Ohio, Kentucky and West Virginia during FY 70 include:

IN	6 projects	4 cities	131 individuals trained
OH	1 project	1 city	19 individuals trained
KY	2 projects	2 cities	60 individuals trained
WV	1 project	1 city	32 individuals trained

- 2 These projects were similar to that described in V, B3. They were in addition to established state and local operator training for entry level personnel and upgrading existing operator personnel. Similar training has been given in many states besides the examples cited. New mandatory certification programs and higher treatment requirements have dictated many new or greatly expanded personnel training activities. Other new training facilities are being developed.

- D Federal support of training through the Training Grants Branch of the Division of Manpower and Training usually is in the form of Grants, Contracts, or Project funding to some delegated agency such as universities, professional associations, consultants.

State or Local Agencies

- 1 Among others these include previously described projects such as III B C D E, IV A.2, C.3.
- 2 Training Grants for academic institutions may include student and project support.
- 3 Community colleges and other training institutions are encouraged by contract.

- E The Direct Training Branch of the Division of Manpower and Training engages in short term intensive training courses for planning, supervisory, technical and instructor personnel.

These are located in Ada, OK, Athens, GA, Cincinnati, OH (National Training Center), Corvallis, OR, Edison, NJ and Fairbanks, AK.

Training support for operator personnel includes:

- 1 Consultation, source information, visiting lecturers, topic background materials or lesson plans, and coordinating assistance for local training.
- 2 Courses specifically directed toward operator instructor personnel on technical background and instruction methodology are offered.
- 3 A catalog of tape/slide audio visual presentations has been developed and is expanding for circulation to state or local training groups as a nucleus for special topic presentation-discussion sessions.
- 4 Study carrels for self-instruction on basic information are being developed.
- 5 Administrative and technical guidance for correspondence training is nearing implementation.

F Technology Transfer Program of the EPA

- 1 This effort is not specifically operator training but plant operation is not possible without versatile and operable plants in line with need. This program is aimed for those who provide the facilities. The Technology Transfer Program of the EPA recognizes that advanced technology will not be used unless three groups apply it. Specific parts of the program are directed toward:
1) the design engineer; 2) the administrator;
3) the public information group.
Technology Transfer was announced as a top priority item of the EPA by Commissioner Dominick at the 43rd Annual Conference WPCF at Boston, MA in October 1970.

- a The Headquarters Advisory Board consists of three Regional Directors, two members of the Office of Water Program and one each from the Advanced Waste Treatment Laboratory and Facilities Construction.
 - b A Headquarters Working Committee includes two representatives from Research and Development, one each from Facilities Construction, Manpower Training and Public Relations.
 - c Each Region has a Working Committee.
- 3 The program evolved from Seminars and Workshop Sessions of the AWTR group that listed 3464 attendees from administrative, consulting, design, technical personnel, professional and lay personnel in 11 major cities from July 1, 1968 to February 1971.
- 4 The first seminar/workshop under the new program other than for organization and development purposes was held at Chapel Hill, NC February 8-9, 1971. One was held in Cleveland, OH in April 1971, one in Boston in May and another at Charlottesville, VA in June 1971.
- 5 The problem is that plants tend to be designed as they have been designed. The Technology Transfer Program is intended to transmit sufficient technology to design and construction engineers so that the most efficient treatment facilities can be designed and constructed at favorable cost/benefit ratios. Plans as of March 1971 include:
- a Program for contributing engineers (By January 1974)
 - 1) 36 seminar/workshops for contributing engineers distributed among all regions.
 - 2) National meetings and conference information, exhibits, talks (4 national meetings).
 - b Program for administrators (By January 1974)
 - 1) Conduct 32 administrative workshops (all regions).
 - 2) Publish 9 State of the Technology Articles in non-technology journals.
 - 3) Conduct an information program for administrators and public officials - semi-technical publications.
 - c Program for public information groups (January 1974)
 - 1) Provide current information to local action groups leaflets - newsletters - lectures - tours.
 - 2) Initiate national and local public information campaign using all media - TV documentaries, public displays.
 - 3) Initiate national recognition program for successful transfer and use of new technology - awards to waste treatment plants.
- G Each Regional Office of the EPA has a Manpower and Training Coordinator for their area.

VI SUMMARY

A Operator personnel training is a function of many interrelated organizations such as government agencies, professional, industrial, manufacturing, supply, educational institutions and all levels of personnel within the organizations. To work, personnel training is a personal responsibility of each individual in the system.

B Personnel training necessarily must be adapted for communication among various levels of responsibility, job descriptions and pre-existing capabilities of the trainee.

1 Entry level personnel require a knowledge of what is expected from their assigned tasks, language training, identification of tools and processes and how to do it practice among assigned tasks.

2 Intermediate level personnel require development of cause and effect relationships, expansion of task oriented capabilities and continuing development in how each bit fits into the whole.

3 Advanced level personnel require emphasis on integration of effort to improve performance with available or obtainable people, equipment and tools.

C Motivation is the basis for growth of personnel capabilities. Recognition of gain as a result of effort expended may take the form of:

1 Monetary reward

2 Public recognition

3 Increased and varied interests

4 Greater responsibilities

5 Improved working conditions

6 Status improvement from a standpoint of job security, choice of assignment, location, etc.

7 A feeling of doing something important.

D Training is a primary responsibility of line operating personnel and their immediate supervision. Planned training is essential for continued development of personnel capabilities. Class work hastens development but applications make it meaningful.

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Additional Reading:

- 1 Municipal Waste Facilities in the United States. U.S. Dept. of the Interior, FWQA, 1968.
- 2 Senate Document No. 49, 90th Congress Manpower and Training Needs in Water Pollution Control, 1967.
- 3 Educational Systems for Operators of Water Pollution Control Facilities, Clemson University and Dept. of the Interior. November 1969, Atlanta, GA.
- 4 Robert F. Mager and Kenneth M. Beach, Jr., Developing Vocational Objectives, Fearon Publishers, Palo Alto, CA.

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WASTEWATER TREATMENT PLANT SAFETY PRACTICES

I INTRODUCTION

A Nature of Hazards

- 1 The hazards to which wastewater treatment plant or wastewater pumping station operators may be subjected in the course of their work, include exposure to:

- a Physical injuries
- b Body infections
- c Noxious gases and vapors
- d Oxygen deficiency

- 2 Hazards are real and preventive steps are necessary if serious damage to life and property are to be avoided.

B Prevention of Accidents

- 1 Occupational hazards can be avoided by:
 - a Proper design of wastewater pumping stations and treatment plants
 - b Use of safety equipment
 - c Efficient administration and the execution of safe practices.

II PREVENTION OF PHYSICAL INJURIES

A Treatment Plant Design

- 1 There are many danger spots around wastewater treatment plant structures at which fencing, chaining, railings and guards are needed to safeguard operators from physical injuries.
- 2 Good judgment and operating experience are needed for the recommendation of adequate fencing and railing protection.
- 3 Machinery should have guards for belts, gears, and all exposed moving machine parts. Adequate space should be provided for machinery to facilitate safe repair and maintenance.

- 4 All electrical equipment and wiring should be properly insulated and grounded. Suitable rubber mats placed before switchboards should be included.
- 5 Space should be provided for stairs and handrails rather than ladders.
- 6 Many treatment plants are attended, particularly at night, by only one operator, whose safety deserves special consideration. Adequate day and night lighting for the grounds and buildings is a necessity.
- 7 Plants using chemicals for treatment of sewage or sludge should be provided with an ample supply of potable water for washing off chemical splashes or spills on the body.
- 8 Fireproof buildings, including sprinkler equipment are desirable. Fireproofing is especially important where large quantities of chlorine are stored.

B Safety Equipment

- 1 Warning signs are needed near dangerous machinery, blind obstacles and for any hazardous location where stumbling may occur.
- 2 Fire extinguishers of an approved design should be placed in sufficient number around the plant.
- 3 For entering deep tanks, and other deep underground structures, the wearing of a harness leather safety belt should be mandatory, and at least two men should be on guard at the surface at all times that workers are in these structures.
- 4 There are times when a life preserver and throw-line on a settling tank rail may prove its worth. Drowning is a mishap that should not occur.

C Safe Practices

- 1 Structures and appurtenances of treatment plants should be kept in good repair and maintained in a tidy condition. Tools should be picked up, manhole covers promptly replaced, and every effort made to promote good housekeeping.
- 2 Walkways should be kept free of grease, oil and ice.
- 3 Safe procedures should be mandatory for electrical maintenance.
- 4 Hazardous assignments should not be undertaken without adequate personnel.
- 5 Accident-preventive instruction of permanently legible character should be prominently posted by management.

III PREVENTION OF BODY INFECTIONS

A Treatment Plant Design

- 1 Clean and well equipped washrooms should be provided.
- 2 Water foot-valves should be provided on potable water supplies. Their use will prevent contamination of plumbing fixtures and reduce the probabilities of reinfection while eating or smoking.
- 3 Clean dressing rooms equipped with benches, mirror, and metal lockers should be provided the workers for changing to and from work clothes.
- 4 Plants should have well lighted and equipped lunchrooms where workers can prepare food and eat in clean surroundings.
- 5 Swing doors (with glass ports) are desirable for use in laboratories, washrooms and locker rooms.
- 6 Cross connections between drinking-water supply and sewage or sludge piping or equipment should be strictly

forbidden and continuous diligence exercised during construction and operation to avoid them.

- 7 All bronze double check valves should be installed on the water main leading to sewage treatment plants. The installation should allow for ready checking of the valves for leakage. The water service pipe for plant drinking water should be taken off the supply main just ahead of the double check valves as an additional safeguard to the employees.

B Safety Equipment

- 1 Emergency first-aid kits should be available for treating minor cuts, burns and wounds.
- 2 A 2 per cent tincture of iodine solution is recommended for immediate use on minor cuts or wounds.
- 3 Rubber gloves should be worn to prevent infection while cleaning clogged sludge pumps, handling screenings, sewage, grit or other filth.
- 4 Coveralls or a complete change to work clothes is recommended during working hours.

C Safe Practices

- 1 A physician should treat all but minor injuries.
- 2 Personal cleanliness should be emphasized and direct contact with sewage wastes should be discouraged.
- 3 Periodic inoculations against typhoid, para-typhoid and tetanus should be made available to personnel.

IV PREVENTION OF DANGERS FROM NOXIOUS GASES AND VAPORS AND OXYGEN DEFICIENCY

A Location of Hazards

- 1 In enclosed sewage screening comminutor rooms where outfall sewers discharge
- 2 In covered tanks where organic matter is decomposing, such as separate sludge digestion tanks, septic tanks, sludge storage tanks, sludge conditioning tanks, or sewage screening bins
- 3 In digestion tank galleries or rooms where sludge gas piping, gas boilers, and gas appurtenances are located
- 4 In sludge gas storage tanks

B Types of Gases

- 1 Dangerous gases which may be encountered occasionally are:
 - a Ammonia (NH_3)

- b Sulfur dioxide (SO_2)
- c Phosphine (PH_3)
- d Ethane (C_2H_6)
- e Industrial waste gases: such as carbon bisulphide, carbon tetrachloride and methyl chloride

- 2 Chlorine handling facilities. Chlorinators should be located in a room which can be heated and has ample ventilation. The room should be fireproof and equipped with automatic sprinklers.

- 3 Equipment for the detection of various gases and oxygen deficiency is shown in Table 1:

TABLE 1
SAFETY EQUIPMENT

Gas or Vapor	Equipment for Detection
Hydrogen Sulphide.....	1. Lead acetate impregnated paper (qualitative) 2. Hydrogen sulphide detector (quantitative)
Methane.....	1. Combustible gas indicator or explosimeter 2. Oxygen-deficiency indicator
Carbon Dioxide.....	Oxygen-deficiency indicator
Nitrogen	Oxygen-deficiency indicator
Oxygen Depletion.....	Oxygen-deficiency indicator
Carbon Monoxide	1. Carbon monoxide indicator 2. Carbon monoxide detector set 3. Carbon monoxide ampoules
Hydrogen.....	1. Combustible gas indicator or explosimeter 2. Oxygen-deficiency indicator
Gasoline	1. Combustible gas indicator or explosimeter 2. Oxygen-deficiency indicator for concentrations over 0.3%
Sludge Digestion Tank Gas	1. Combustible gas indicator or explosimeter 2. Oxygen-deficiency indicator
Chlorine	1. Aqueous ammonia 2. Odor
Ammonia.....	Odor
Sulphur Dioxide.....	Odor
Ethane	1. Combustible gas indicator or explosimeter 2. Oxygen-deficiency indicator

C Safety Equipment

- 1 The following safety equipment for the plant should be included in the specifications.
 - a Safety harness and recovery line
 - b First-aid kit
 - c Fire extinguishers (carbon dioxide and soda ash-acid types)
 - d Portable combustible gas indicator
 - e Combustible gas alarms in hazardous locations at large plants
 - f Oxygen deficiency indicator
 - g Portable air blower
 - h Hose mask or compressed-air, demand-type mask
 - i Two or more canister gas masks or compressed-air masks for chlorine leaks
 - j Miner's safety-cap lights

V SUMMARY

Because of the many hazards from gases, infection and physical injuries in the operation of wastewater treatment plants, maintenance of such systems can be a dangerous occupation if adequate safety precautions are disregarded. By the use of sensible safety measures, these dangers can be minimized and serious accidents can be avoided.

Cooperative efforts of designing engineers in providing safe structures and of all employees in exercising reasonable precautions in the course of their work are needed. The responsibility of management to provide adequate training in the safe operation of all aspects of the wastewater treatment plant is also mandatory.

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This outline was prepared by P. F. Hallbach, Chemist, National Training Center, OWP, EPA, Cincinnati, OH 45226.

LABORATORY EXAMINATION AND PLANT CONTROL

I PURPOSE

The purpose of laboratory examination of wastewater is -

- A To obtain the most efficient control possible of the plant processes.
- B To produce the best final effluent possible.
- C To have good records of
 - 1 Sewage and effluent strengths
 - 2 Unit efficiencies
 - 3 Unit loadings
 - 4 Possible shock-loads due to industrial losses.

II It is obvious that small cities cannot afford, and perhaps do not need, as complete a set of tests and records as large plants should have. However, small plant operators should be able to make simple tests regularly and keep records which show the effectiveness of unit operations.

- A Simple tests for small plants. There are a number of simple tests which can be run by any plant operator, regardless of lack of technical training.
 - 1 Imhoff cone test (settleable solids)
 - 2 Methylene blue stability test (any druggist can make up the solution).
 - 3 Mixed liquor sludge settling test. Small activated sludge plants will not have available equipment for running suspended solids in the mixed liquor and therefore cannot make the sludge index computation.
 - 4 pH. The pH of sewage or the supernate above sludge may be made colorimetrically, or even better with glass electrode units even by non-technical operators.
 - 5 Chlorine residual by color comparison in commercial comparators.

III Larger plants should have available balances, drying ovens, electric muffles and incubators for the quantitative estimation of pollution, unit loadings and efficiencies.

A Quantitative Tests

- 1 Suspended solids in raw, primary and final effluents.
- 2 Mixed liquor solids in activated sludge plants
- 3 Total and volatile solids in raw, treated and digested sludges
- 4 Volatile acids for the control of loaded sludge digestion tanks
- 5 Dissolved oxygen and BOD for river
- 6 Biochemical oxygen demand for raw sewage, primary and secondary effluents, and for plant evaluations
- 7 Chlorine residual, chlorine requirement and coliform group density

B Occasional Tests (Qualitative and Quantitative)

There are numerous tests which are of value in special cases due to industrial wastes, and special conditions.

- 1 Heavy metals and cyanides
- 2 Phenolic tests
- 3 Sugars, starches and carbohydrates
- 4 Acids and alkalies
- 5 Phosphates
- 6 Chlorine demand
- 7 Ammonia, nitrite and nitrate nitrogen

IV SAMPLING AND REFRIGERATION

- A Grab samples should only be analyzed in small plants with limited personnel or in special cases such as dissolved oxygen which must be determined immediately.

B In small plants, grab samples of sewage and effluents should be taken between 11 a.m. and 1 p.m. so that they represent the strong sewage of the day.

C Composite samples should be collected if at all possible, the ideal being 24 hourly samples composited proportional to the rate of flow.

D Samples when not analyzed immediately should be kept at 4°C to prevent, as far as possible, further decomposition.

E Where industrial shock-loads are important items in operation, I recommend that separate 4 oz. samples of raw sewage be collected hourly, held in the refrigerator and inspected or analyzed by spot or rough tests to locate the hour and rough estimate of concentration which came down the sewer.

V NOTES ON RECORD SHEETS

A A good set of records should be kept at even the smallest sewage treatment plant. However, the number of items kept daily, weekly or occasionally will increase with the size of the plant. Only a minimum of records can be kept by an operator who spends only part time daily at the very small plant.

VI DISCUSSION OF CHEMICAL EXAMINATIONS

A The Imhoff Cone test for settleable matter is a very valuable test both for the operation of a small plant and the superintendent or chemist of a large plant. It has lost favor in recent years because of its simplicity, and because the results are not convertible into quantitative expressions such as pounds per day, or lbs. per cu. ft. digestion capacity.

1 However, there is no one test that tells the trained operator more about the satisfactory operation or the malfunctioning of the plant processes.

a Primary tanks should show a 90% removal of solids as measured by the mg/l in the bottom of the cone after 1 hour settling.

b Secondary settling tanks following trickling filters may not show better than 80% removal.

c Activated sludge effluents from the final tanks will show little or no sludge in the cone.

2 The clarity of the liquor in the cones indicates the efficiency of the secondary oxidizing processes of filters or activated sludge.

B Relative Stability or Methylene Blue Test (MB)

1 In this test the blue color in the incubated bottle persists until all the dissolved oxygen (D.O.) and then all the nitrite (NO_2^-) and nitrate (NO_3^-) oxygen is used up by the bacterial action on the organic matter remaining in the effluent. Therefore it is a test for the amount of stabilization that has taken place in the trickling filters or the activated sludge processes.

2 In trickling filters the quality of the final effluent is seldom very good until after nitrification is well started (i.e. 1 to 2 ppm) and the MB test of 8 to 10 day stability is a good indication of satisfactory operation of the filters.

3 The activated sludge process is able to remove or oxidize most of the organic matter before there is very much nitrification and it is possible to produce an effluent of 5-10 mg/l of biochemical oxygen demand (BOD) without any nitrates. Such an effluent may have only a 2 or 3 day stability because of the lack of nitrates in the effluent, and therefore the MB test is not such a good test for activated sludge effluents.

C Mixed Liquor Settling Test

1 This is the first step in the determination of the sludge volume index (SVI) and is usually done by the operator immediately after collection. It is usually done in a 1 liter graduated cylinder, the volume of the settled sludge is read in mls at the end of 5 and 30 minutes.

2 A good sludge should settle so that the 5 minute volume is twice or less than twice that of the 30 minute volume. For example, a bulking sludge would be indicated by a 5 minute volume of 700 and a 30 minute volume of 250.

3 For the determination of the SVI a sample of the mixed liquor must be examined in the laboratory for mixed

liquor suspended solids and the SVI calculated from the usual formulae.

- 4 A note of caution! SVI should not be determined on mixed liquors containing more than 3000 mg/l Suspended Solids (SS). If the solids are higher the sample should be diluted with plant effluent before settling and the SS determined on the diluted sample. The SVI is calculated from the data on the diluted sample.

D Dissolved Oxygen (D.O.)

Even in very small activated sludge plants the D.O. in the mixed liquor should be determined regularly, preferably near the inlet and the outlet ends of the aeration tank.

- 1 This may be done colorimetrically by the Winkler azide reagents on the settled mixed liquor that has been deactivated with the copper sulfamic acid inhibitor.
 - a The iodine color is compared to standard colors made up of potassium dichromate and cobalt chloride or in a color photometer.
 - b The iodine color may be titrated with sodium thiosulfate. This is more accurate than the colorimetric procedure.
 - c Both (a) and (b) are subject to considerable error if the D.O. is less than 1.0 mg/l because of aeration in handling the sample before fixing the oxygen with the Winkler reagents.
 - d The D.O. is determined best by the various D.O. probes which are now on the market, and which can be placed directly in the aeration tank. The D.O. is determined on a scale similar to reading a glass electrode-pH meter. The only problem is keeping the probe standardized. Some probes are much more stable than others.
 - e The D.O. may be determined accurately in the laboratory by a chemist using colorimetric, volumetric, or potentiometric methods. However, all methods are standardized against the Winkler azide modification.

- f Occurrence. Very little or no D.O. is found in most sewages and primary effluents but greater than 1-2 mg/l should be found in secondary effluents.

E The Biochemical Oxygen Demand (BOD) is the oxygen utilized in the oxidation of the impurities in the wastewater. Historically it was called Biological oxygen demand and was determined by the reduction of nitrate. As presently determined it may include only the organic or the organic and inorganic oxygen demand depending on the way one calculates the oxygen depletion.

- 1 In the dilution technique the demand is usually calculated from the difference of the D.O.s of the diluted sample near the beginning of the incubation period and at the end of 5 days. This usually allows time for the chemical oxidation of sulfites, sulfides and other inorganic oxygen demand reactions to take place before the first D.O. is determined.
- 2 In the direct addition of the sample to the BOD bottle, the D.O. at zero time is calculated from the incubated dilution water D.O. and the sample D.O. If this calculated D.O. is used with the 5 day D.O. the resulting BOD will include the immediate (chemical) oxygen demand which standard methods abbreviates as IDOD. The IDOD can be determined by running an additional D.O. 15 minutes after the dilution was made. Usually this is small in amount, but with some industrial wastes it should be determined so that both the IDOD and the total oxygen demand is determined.
- 3 Toxic Dilution Water or Toxic Wastes

The dilution water must be free of toxicity or it will produce low results.

 - a These toxicities may be detected by setting up five increasing dilutions of waste such as 1%, 1.5%, 2%, 2.5%, and 3%. If there is no toxicity the BOD results should be randomly distributed such as 210, 190, 200, 205, 198 mg/l.
 - b If the dilution water is toxic the results will usually slide upward with increasing waste concentrations i.e., 170, 180, 190, 200, 210 mg/l.
 - c If the waste is toxic, the slide will be increasing BOD with increasing dilution

i.e. 220, 200, 190, 180, 170 mg/l.

F Rates of Oxygen Utilization, Uptake, K_{1a} , α and β

The oxygen probe has made it possible to study the rates of oxygen uptake and oxygen utilization in the activated sludge process, and although the methods for determining some of these quantities are not standardized, their use is appearing in the literature regularly.

- 1 Oxygen utilization in mixed liquor presents no problem. The mixed liquor, immediately after collection is saturated by shaking, the probe inserted and the decrease in D.O. recorded each minute over a period of 5 to 10 minutes, and the results are reported in mg of O_2 /l/hour, or the specific uptake in mg of O_2 /l/hr/gram of mixed liquor solids.
- 2 The oxygen uptake rate K_{1a} , and the related constant α is not so easily determined in mixed liquor, because they are affected by the size, shape and kind of aeration equipment used in the aeration tanks and in the laboratory. They are determined by deaerating the mixed liquor (immediately after sampling with nitrogen gas and then aerating the mixture). The D.O. probe is inserted and D.O. readings made each minute until saturation is approached. The dissolved oxygen deficit ($C_s - C_t$) is plotted on the log scale of semilog coordinate paper against the time in minutes on the arithmetic scale. This should be a straight line intercepting zero time at C_s .

K_{1a} is the slope of this line and is calculated as follows:

$$K_{1a} = \frac{2.3 \log \left(\frac{C_s}{C_t} \right)}{t \text{ in minutes}}$$

This must be corrected to 20°C as follows:

$$K_{1a} \text{ (at } 20^\circ\text{C)} = \frac{K_{1a} \text{ (at } t^\circ\text{C)}}{1.02^{(t-20)}}$$

$$\alpha = \frac{K_{1a} \text{ of mixed liquor at } 20^\circ\text{C}}{K_{1a} \text{ of water at } 20^\circ\text{C}}$$

There are so many varying conditions and temperature corrections in the determination of K_{1a} , particularly

in mixed liquor, that laboratory operators are not able to put much confidence in these parameters as methods for controlling operation.

- 4 β is easily determined being the ratio of D.O. at saturation in the waste divided by D.O. at saturation of water. This value is usually .95 to 1.00.

G Suspended Solids

This determination is simple to do and is basic in evaluating the efficiencies of primary and final settling tanks, loadings in digesters, and mixed liquor solids in the activated sludge process.

- H Total and Volatile Solids of sludges is likewise an easy test and the results are used to guide the operators in sludge withdrawals and to indicate the efficiency in the destruction of volatile solids in digesters.

- I Volatile Acids and Alkalinities in the supernatant liquor are good indicators of trouble in digester operation, however the falling off of gas production will usually indicate trouble ahead even before volatile acids indicate the trouble.

- J Hydrogen ion concentration (pH) is of value in

- 1 Raw waste to indicate high acidity or alkalinity which may be detrimental to the biota of the secondary treatment or of the sludge digestion process.
- 2 The digestion process as an indication along with alkalinity, volatile acids and gas production of the quality of the digestion process.
- 3 Although colorimetric methods may be used, the pH meter (using the glass electrode) is by far the best for waste treatment analysis.

- K The Chemical Oxygen Demand (COD) has a very definite place in our laboratory procedures. Its popularity is due to its simplicity and short time requirement. It is of value in predicting the probable 5 day BOD on the first day and long term demands of low rate systems.

- 1 The standard method using a 2 hour reflux period approached a total carbon determination. If shorter periods of refluxing are used or lower temperatures,

a less complete carbon oxidation takes place and the ratio of COD as determined to 5 day BOD will be reduced.

- 2 On raw domestic sewage the ratio of the 5 day BOD to the 2 hour COD is usually 0.65-0.75, but with industrial wastes the ratio must be determined experimentally.
- 3 On secondary effluents the ratio is often less than 0.05 to 0.1 because of the COD of stabilized organic matter which has little or no BOD.
- 4 COD is therefore unsatisfactory in estimating the degree of stabilization of organic matter in the purification processes. It is a good index of the strength of industrial wastes.

L The Nitrogens

- 1 Ammonia nitrogen is not usually determined routinely in treatment plant operation. It should be run occasionally so that the operator knows that there is the minimum amount for proper biological activity.
- 2 Nitrites are usually not present in significant amounts and are not determined except for special reason.
- 3 Nitrates are determined on trickling filters and activated sludge effluents to indicate the degree of oxidation that has taken place.

M Phosphates have not been determined in wastes on a routine basis until recently. The present interest is due to the possible fertilization of our water courses and thus the promotion of algae and other plant life therein.

- 1 Before the days of synthetic detergents the phosphoric acid content of sewage was reported to be between 5-8 mg/l. As P this would be 1.6 to 2.2, but since the introduction of synthetic detergents this quantity has increased to values of 25 to 35 mg/l.

- 2 There are numerous forms of phosphorous in sewage but it is usually determined as total phosphorus P.

N Chlorination of final effluents is becoming a standard procedure and where used the following tests are applicable:

- 1 Residual chlorine
- 2 Chlorine requirement
- 3 Bacteriological analysis

- a Total bacteria count or algae
- b E Coli by dilution or direct count
- c Coliform group

O There are other tests that are of value in plant operation, but only made for special purposes such as alkalinity, acidity, heavy metals, etc.

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WASTEWATER TREATMENT FACILITIES MAINTENANCE

I INTRODUCTION

A Maintenance from an engineering standpoint includes keeping plant equipment, buildings, grounds, and related facilities in condition to perform its intended function when needed. Keeping it neat and clean is a concurrent essential.

B Maintenance is not a design, construction or operation function because the facility has been built; yet maintenance enters all of these areas to improve operating potentials, to correct breakdown oversite or errors, to modify for changing situations, increased treatment requirements, and/or loading.

C Maintenance means to anticipate:

- 1 To prevent mishaps that may be prevented from causing serious performance disruption.
- 2 To be ready for prompt repair or replacement of items that are subject to rapid wear frequent breakage, or hard service conditions.
- 3 To replace with an improved model better suited to the conditions.
- 4 To modify operations to improve operational performance.

D Maintenance must be managed - Preventative maintenance requires integration of plans, staffing, operation, stockroom, tools, lubrication, and records. All require scheduling to perform required service with minimum disruption of operating routine. Alternate routing or standby equipment to maintain effluent quality requires advance planning. Very few breakdowns occur without some advance warning. Part of good management is the practice of questioning - what can be done if -? Then, in line with priority, get ready with tools, equipment and planned procedure.

E Records are essential part of good maintenance to guide stock control, routine service, replacement, and future selection of equipment. Master cards giving installation and operating particulars are fundamental. These should be combined with running records giving service dates and unusual operating events. Any maintenance service performed becomes a note on the running record to be retained for future guidance. Running records and stock control records must be current and complete or they aren't useful.

F Safety is a first consideration in maintenance. This crew encounters more hazards than any crew in the plant because of the nonroutine, emergency nature of the work. Safety consciousness and close safety supervision are important for continued effectiveness.

II MAINTENANCE MANAGEMENT

A Maintenance is a direct responsibility of the individual in charge of the facility with guidance and limitations established by local, State and Federal authority and the help of manufacturers, suppliers, consultants.

- 1 Decisions must be made concerning in-house or contract maintenance, delegation of areas of responsibility and lines of authority.
 - a What services are performed by operators/by maintenance? i.e., who does minor adjustments, lubrication, on what?
 - b What types of equipment will be serviced in house/by contract?
 - c Set up inspection and reporting routines.

- d Set up schedules for routines and priorities for nonroutine services.
- 2 Establish financial controls and essential records for implementation of the stated objectives. Establish an adequate budget for personnel, supervision, stock, records, expendable and nonexpendable materials, equipment, tools and contingency funding.
- 3 Assemble a staff including supervision, labor, specialty assignments such as electrical, mechanical, painters, carpenters, clerks, etc. in line with intended requirements.
- 4 Integrate current priorities in line with need. Supervise overall operation and performance controls.

III MAINTENANCE RECORDS

Records sometimes appear to be like the tail wagging the dog; if the tail can be used as a handle to prevent disaster -it's worth keeping.

A First requirements include construction diagrams and plans locating essential equipment, buried or in view.

- 1 It's important to know where it is, clearance, levels, grade, footing and bearing characteristics.
- 2 These plans should be kept up to date with date and signature whenever modifications require changes from originals.

B Plant and equipment instruction manuals are needed as reminders for operating and maintenance guidance. Organize them for access.

- 1 Each piece of equipment should have a master card on file giving name, model, serial number, manufacturer, parts sources, lubricants, lubrication frequency and pertinent precautions.

2 A copy of this master card should be posted near the equipment along with a running record card indicating maintenance service performed, date, initials of the individual and notes pertinent to the service record. Entries should be kept up to date and renewed as necessary. This is a unit history, retain them.

3 Equipment instructions commonly indicate likely maintenance stock requirements for replacement along with numbers and sources. These should be used as guidelines. The stock quantity may vary with equipment age, type of service the running record or parts availability. This requires close control to decrease useless stock accumulation while having what is needed when it's needed.

4 Running records on maintenance are a very effective tool for guidance in preventative maintenance, checking maintenance performance, and operating routine, selection of equipment for future use and stock control. Keep them simple, concise and complete.

5 Manufacturers guidelines on maintenance and service instructions should be carefully followed. Lost information usually can be replaced by the manufacturer or supplier. Use them - they are based upon experience. If there is any question regarding the equipment, contact the manufacturers representative for recommendation.

IV LUBRICATION OF EQUIPMENT

A Manufacturer's recommendations usually specify type and quantity of grease or oil to be used with their equipment and type of service. Low quality substitutes or improper lubricants are extremely poor economy. Any questions on trade names or types of lubricants can be clarified by the manufacturer's representative or a qualified lubrication engineer.

- 1 Properly lubricated equipment in regular use may be expected to have a reasonably predictable service life.
- 2 You may have a continuous or drip feed of oil, a sealed bearing with grease or oil fill, a splash type of lubrication or other lubrication system. Each specific system has its own characteristics and routine maintenance. Use conditions such as heat, load, speed, continuous or start/stop operation, moisture and dirt exposure has an effect upon lubrication. The manufacturer attempts to design a particular unit for an intended use and selects a mode of lubrication suited to that application. Experience guides them on what may be used where.

Use this guidance in your selection of lubricant type, grade, and weight, application and frequency. Failure to do so may be expensive in repair cost, warranty protection and down time.

- 3 Lubricants may be used in a gravity or force feed situation intended to clean a working bearing surface. Leakage rate may be specified. If so, keep it that way. Splash bearings specify a certain oil level in some form of pan. Specified level control limits are usually marked to guide maintenance. Enclosed bearings may require special handling and filling precautions. If you have two plugs on a sealed bearing, one for grease application, and one to allow old lubricant to be forced out, be sure that both are open during recharge. In some cases, the grease is to be applied while running, or to be run a few moments before inserting caps. Follow instructions for the particular unit carefully.
- 4 Dirty oil or grease is not a good lubricant. Your equipment usually has a cleaning interval and procedure. You may have an oil filter to protect the equipment. Follow instructions carefully.
- 5 New or standby equipment is a special problem in lubrication. Mishandling means that either the equipment won't work when you need it or fails after a

short period of operation. Long standing may mean a dry bearing surface from which lubricant has been forced out with concurrent pitting, corrosion, or collection of extraneous foreign materials.

- a If you expect to purchase equipment that will not be installed promptly request standby protection from the manufacturer and specification on preservice cleaning and relubrication.
- b Equipment subject to pre-installation delay of more than one month needs protection. Contact your manufacturer's representative for recommendations, then follow it.
- c Installed equipment for standby or emergency use is intended to be operated at regular intervals to keep it serviceable. The operating interval depends upon type of equipment and service conditions. Many instances of failure of a pump, motor, valve line or other mechanism are traceable to the fact that the unit was installed and forgotten. A standby pump may be kept serviceable by alternate operation programming on a cycle, weekly or other relatively short interval. A valve or gate may require checking cleanout, and full range operation until it functions smoothly at intervals of 1 to 12 months depending on the unit and its location.
- 6 Follow instructions diligently but be sure instructions, unit and conditions match.

V EQUIPMENT REPLACEMENT AND REPAIRS

- A Magnitude of maintenance capability depends upon competence of the staff in handling a particular problem, availability of the tools, repair parts, replacement equipment and competence with the particular equipment to be serviced. A serious deficiency of any of these qualifications calls for a choice

of correcting the deficiency, contract negotiation for repair or replacement or combinations of both.

- 1 Many small plants use an outside consultant to manage major repairs while in plant personnel provide for lubrication, repacking, and minor adjustment or replacement.
- 2 Contract services for maintenance are common. Separate contracts on a manufacturer or supplier basis or a maintenance consultant contract are possible on a general or selected basis.
- 3 A large installation may have an elaborate engineering staff including mechanical, electrical, welding, rigging and installation capabilities with backup personnel and equipment for them. A choice is still necessary on each project or job to determine whether it is preferable to perform the services with staff personnel or contract with the manufacturer or specialist.
 - a Thorough knowledge of the equipment to be repaired or replaced is essential including the problem cause and cure, installation details and availability of replacements.
 - b Precise conditions now must be known. This means careful examination of available data including dismantling for inspection.
 - c Dismantling means workable pre-planning on means to lift heavy objects out of and back into place, reconditioning and replacement of essential parts, reinstallation, alignment and reconnection for service as prescribed for the situation.
 - d Repair functions have to be performed without avoidable interruption of operating performance and with regard for safety of maintenance and operating personnel.

B Proper use of Tools and Equipment

Tools are the stock in trade of the maintenance group. Each one is made to serve as an extension for hands, feet, or muscle power to do a specific job. Properly used they are safe and effective. Improperly used, they become a menace to personnel and property. This section is intended for discussion of certain selected misuses of tools and equipment. Other articles in books, periodicals and trade literature discuss particulars. Equipment descriptions include operating precautions - use them.

- 1 Motorized vehicles, lifts, conveyors are a common essential. Use them productively - don't fight them. Respect their capabilities for benefit or damage; operate defensively and watchfully. Use a backup man to help judge clearance when necessary. Overloads, unbalanced loads, improper rigging, inadequate bases of support, or misuse of power are common causes of serious damage.
- 2 The gasman's pliers are versatile and handy but they were not made to tighten hex nuts. Be sure that your tool fits securely and is appropriately designed and sized for the job.
- 3 Ladders, either built-in units or the movable variety commonly are misused. Check structural characteristics before use. Are they sound, firmly anchored, can you obtain a firm grip on the rungs? It is possible to carry objects while climbing up or down ladders. Proper use limits this to a line with which you can raise or lower objects after reaching the work area. Wherever possible use a wench or other mechanical lift for lowering or raising manpower and tools particularly when working in wet wells or other places where the bottom may be slippery.
- 4 Proper ventilation equipment is mandatory before entrance to wet wells,

manholes or other subgrade enclosures. Use this equipment before entry for a sufficient time to insure acceptable fresh air at the working site. Use a lifeline and backup crew for protection from mishaps.

- 5 Explosive gases may collect in many below grade enclosures. Ventilate first then use non-sparking tools.
- 6 Avoid application of sudden or excessive pressure on any given tool. Pipe extensions or hammers were not intended to be used on wrenches. A frozen nut may be stubborn. If penetrating oil doesn't work cut it off or chisel it. Overtightening nuts means stripped threads, strained or misaligned tool or hookup, and a tough loosening job next time. Use torque wrenches on critical jobs and curb your strong-arm boys with them.

VI BUILDINGS AND GROUNDS MAINTENANCE

A neat and clean facility is your best public relations tool. It's also an important cue for staff personnel to keep them proud, happy, and more careful.

- A Tanks, channels and operating structures require regular cleanup, fix up, and paint up. Railings, grids, walkways require special corrective action for looseness, corrosion, and damaged surfaces.
- B Grounds require regular mowing. Plantings at suitable locations add much to the impressions of the plant and its management. Prevent accumulation of unused equipment or junk in a haphazard fashion. If you must tear up the grounds for a given job, regrade it promptly.
- C Building roofs, gutters, windows, side-walls, steps, screens, trim, inside and outside require regular maintenance, repair and repainting as necessary.
 - 1 Surface preparation and repair is fundamental. It serves to protect the structure and everything inside, and looks better.

- 2 Good materials - lumber, metal masonry or protective coatings are the most economical.

VII SUMMARY

A Maintenance of equipment is based upon the following essentials:

- 1 Proper installation and checkout.
- 2 Effective lubrication.
- 3 Competent operation by trained personnel.
- 4 Frequent inspection and check for unusual noise, heat, vibration-prompt reporting and followup with an effective trouble shooting and correction routine.
- 5 An adequate staff for maintenance and funding for tools, parts, replacement and backup support.
- 6 A workable system of reporting, stock control, information retrieval, and line of authority designating individual responsibility in a clear concise manner.

B Any given problem may be handled effectively by the maintenance crew if -

- 1 Personnel have a working knowledge of the particular units, function and characteristics.
- 2 Have knowledge of pertinent observed characteristics indicating malfunction.
- 3 Have the capabilities and competence to make a thorough inspection including dismantling to check compliance with equipment specifications and mountings as prescribed.
- 4 Have or can obtain replacement parts observed to be defective.
- 5 Have the capabilities and competence available to reassemble as intended and check for smooth operating function.

- 6 Have alternate routing or standby equipment to maintain acceptable treatment performance during down time.
- C To function, any maintenance program must be properly managed, supervised and implemented with competent trained people and the necessary tools, parts and equipment for the job.
- 1 Each individual should clearly understand his responsibility in the team.
 - 2 Instructions should be clear and concise.
 - 3 Records must be simple and direct. They must be used for a purpose - not just "collected."
 - 4 The program must be backed by interested management to schedule, establish priorities, and backup as needed.

Acknowledgments and additional reading materials in this outline came from many sources too numerous to mention individually. Their help is appreciated as a group. This author used and you may use:

- 1 Manufacturers equipment brochures.
- 2 Training course material from local, State, Federal and Professional Associations.
- 3 Articles on the topic in books, periodicals, specials.

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PUMP MAINTENANCE

I INTRODUCTION

A Pumping is a fact of life in wastewater treatment plant operation. You probably have sewage pumps, air pumps, sludge pumps, proportioning pumps for oil, fuel, or chemicals, recirculating pumps for gas process waters or sludge. Some pumps are intended for continuous operation, some for intermittent operation. You are likely to have many different sizes and several different types of pumps available for different purposes.

B You will have to learn to live with pumps. With appropriate lubrication and care of them, your life will be easier and much more productive.

II ORGANIZATION FOR PUMP MAINTENANCE

A It is assumed that your plant has been checked out for service and is in operation. Start up routine is a function of the representatives of the plant facility, the consultant, the contractor and the equipment manufacturer, or supplier. Hopefully, you were a key part of this phase of operation to learn as much as possible from it.

B Your plant records should contain specific instructions, drawings and descriptive material for each pump in service. Assemble and file them in an orderly fashion so that you can locate them when you need them.

C Each pump should have a record card including make, model serial number and date of installation; name of the supplier or service representative, and lubrication instructions. This card should be posted preferably in a suitable place in the pump vicinity so that a running record on it can be maintained. Date of lubrication, cleanup, notes on operating problems, and initials of the individual making the entry are regularly sought. As soon as one card is filled, permanently file it and replace it with a new record card.

III PUMP BEARINGS

Pump bearings are one of the major sources of trouble. Daily observations are necessary to avert trouble.

A Any irregularity in noise vibration temperature or flow is an indication of trouble and should be closely watched. This is applicable not only to pumps but to pump drivers as well.

B Lets assume that you are starting a new pump or restarting one that has received a cleanout or overhaul. Check for proper greasing, pump rotation and alignment.

1 Check bearing temperature for the first hour of operation or until they reach a stable running temperature under conditions of use. Be sure that an approved bearing temperature device is used - hand contact may be handy but it is not advisable because a "cooked" hand is not very useful for you or for the record. If the temperature does not stabilize within a reasonable running range find out why before serious difficulty develops.

2 If the temperature stabilizes in an acceptable range, you probably are in business for 1000 to 2000 hours of operation depending upon severity of service such as dampness, corrosivity, abrasives, etc.

3 Learn to recognize the sound of the unit under favorable use conditions. Air leakage into the suction side, overloads, discharge obstructions, loose anchorage and many other problems may be detected by sound changes.

C Greasing during service depends on the operation and the equipment.

1 For 24 hour service, add grease every 6-12 weeks. Clean out bearings and bearing housings every 12-18 months with hot (200-240°F) kerosene flushing. Follow with a light mineral oil flush and repack the bearing with the recommended grease.

2 For 8 hr/day service, add grease every 6-8 months.

3 For light duty or standby service, run pumps for 1 to 2 hours every month to prevent rust accumulation. Have the bearings cleaned and flushed (hot kerosene 200-240°F) once yearly and repacked with recommended grease to

prevent damage due to oxidation of grease.

- 4 Grease would normally be a good quality No. 2 moisture resistant variety for normal temperatures. A No. 1 grease is used for higher speeds or lower ambient temperatures. Where bearing temperatures are up to 150°F; a lime base inhibitor is normally used and a lithium base generally used where the bearing temperatures are higher than 150°F. Check the pump manufacturers' recommendations.

- 5 For bearings equipped with grease plugs, remove both takeout plugs and do not over fill during repacking. Increased temperatures during running will expand the grease and cause a dangerous pressure rise after replacing plugs which is likely to damage the bearing. It may be advisable to run the unit for a short time before reinserting the second plug to get rid of excess grease.

- 6 A constant level oiler is usual for oil lubricated bearings. A high quality turbine or hydraulic oil containing rust, oxidation, and foam inhibitors is recommended. Check equipment and lubricant manufacturers recommendation. Normally a 10-W oil is used for bearing temperatures of 125 to 145°F and a 20-W oil for bearing temperatures of 145 to 180°F. Note - The oiler level must be as shown on drawings or bearing housing for a high oil level is as bad as overgreasing a bearing. A complete oil change is recommended every 6 to 8 months of average operation. More often if the atmosphere is damp and corrosive as it usually is in sewage treatment plants.

- D Long term storage without operation requires special care on either grease or oil lube bearings to prevent bearing troubles. If a pump is likely to be on standby for more than one month:

- 1 Request the manufacturer to prepare it for long term storage or
- 2 Coat shaft and bearings with heavy grease to prevent rusting.
- 3 Before use, clean by hot flushing as described in III. C. I. and replace with the recommended lubricant.

- 4 Almost all initial bearing failures are traceable to neglect of storage considerations.

IV PUMP PACKING

- A Pump packing may be carefully done either at the factory or by in-house replacement. Its service life generally depends on careful adjustment and checking of conditions to insure that it does prevent gross pump leakage without excessive heating or wear on the shaft sleeves.

- B Remember that the packing of any pump is cooled and lubricated by the leakage of liquid from the packing or "stuffing box."

- 1 Never tighten the packing gland so that leakage is stopped completely. A steady rate of 10-15 drops/minute of leakage through the packing is the proper rate.

- 2 Never tighten packing on a unit that is not running.

- 3 Start the pump, allow it to leak fairly rapidly for a few minutes running. Tighten the packing gland evenly and a little at a time allowing it to run for a few minutes after each take-up stage. (Use hand tightening)

- C Once the packing is old and worn or leakage cannot be controlled readily by packing gland adjustment, repack the stuffing box - never add one more packing ring to take up the "slack" and give a bit more adjustment.

- 1 Remove all old packing, the lantern ring and/or seal cage. Careful - these are generally "stuck" in place. There is no easy removal. Your service representative generally can supply tips to help you remove packing in your particular type of pump without damaging the shaft sleeve or housing.

- 2 After removal of stuffing, clean the box thoroughly. Inspect the box, shaft sleeve, lantern ring, and/or seal cage. Make certain that the shaft sleeve is not unduly worn or damaged. You will waste time and material repacking if it is.

- 3 Cut the packing about 1/16 inch longer than measured - this will insure that the outside diameter of the packing ring will hug the stuffing box rather than the shaft sleeve and cause

excessive wear. Use a sharp cutting tool to get a clean cut. The usual packing for water and sewage service is braided graphited asbestos. Never use flax as it will result in rapid shaft sleeve wear. Check with the manufacturer or service representative.

- 4 When inserting packing, push the first ring all of the way back into the housing evenly. Rotate each subsequent ring so that the cut ends are staggered 90 to 180°. Push each one all of the way back into the housing before starting the next. Make certain that the lantern ring or seal cage is directly under the seal water connection. Continue adding packing rings individually according to specifications. Replace packing gland. Take up slack, then back up to a loose fit.

- 5 Inspect the pump installation before startup. Are your valves, power circuits, pump and lines ready to go? If so, turn on the seal water and start the pump. Let the stuffing box leak freely for 10-15 minutes, then gradually tighten the packing nuts by hand. Watch the temperature rise; if packing nuts are tightened too rapidly, the packing will heat, glaze and possibly score the shaft sleeve.

- 6 Caution - never tighten the packing gland so that all leakage is stopped. A slow constant drip is what you want. Check daily and adjust as needed.

V SEMI ANNUAL OR ANNUAL INSPECTIONS

- A Check the running records. Have the units been serviced on schedule? Have there been notations of characteristics that suggest operating difficulty later?
- B Clean the bearings and replace with grease or oil as specified on the running record. Replace stuffing box packing after cleaning the housing as specified on the running record. Check packing gland leakage and freeness. Oil and free-up packing gland nuts and bolts.
- C Check capacity and head to determine if wearing ring clearances are OK. Complete overhaul is not ordinarily needed unless problems such as reduction in capacity or pressure, vibration, high bearing temperatures are evident.

- 1 If it is necessary to dismantle the pump,

protect all machined surfaces from rust or damage, clean and paint casings, check wearing ring clearances with the pump manufacturer, check shaft sleeves and replace if worn. Check fit at the the impeller hub and condition of the shaft under the sleeves. Remember that mismatched or poorly fitting replacements are likely cause early failure. Either know what you are doing or call in someone who does.

- VI Some of the more common sources of trouble are listed below. The operator often can avoid unnecessary expense by careful consideration of the causes outlined.

A Failure to Deliver Water

- 1 Pump not primed
- 2 Insufficient speed
- 3 Discharge head too high (greater than that for which the pump is rated)
- 4 Suction lift too high
- 5 Impeller passages partially clogged
- 6 Wrong direction of rotation

B Insufficient Capacity

- 1 Air Leaks in suction piping
- 2 Speed too low
- 3 Total head higher than that for which pump is rated
- 4 Suction lift too high
- 5 Impeller passages partially clogged
- 6 Mechanical defects:
 - a Impeller damaged
 - b Wearing rings worn (where applicable)
- 7 Foot valve too small or restricted by trash
- 8 Foot valve or suction pipe not immersed deep enough

C Insufficient Discharge Pressure

- 1 Speed too low

Pump Maintenance

2 Air in water

3 Mechanical defects:

a Impeller damaged

b Wearing rings worn (where applicable)

D Pump Loses Prime After Starting

1 Leaky suction line

2 Suction lift too high

3 Air or gases in the liquid

E Pump Overloads Driver

1 Speed too high

2 Liquid pumped of different specific gravity and viscosity than that for which pump is rated

3 Mechanical defects

4 Packing gland too tight causing excessive friction loss in box

F Pump Vibrates

1 Misalignment

2 Foundation not rigid

3 Impeller partially clogged, causing unbalance

4 Mechanical defects:

a Bent shaft

b Rotating element binds

c Worn bearings

This outline was prepared from materials supplied by C. M. Robertson, Jr., Worthington Corporation, 1077 Celestial Street, Cincinnati, OH 45202

METHODS FOR ACHIEVING HIGH BOD AND SOLIDS REMOVALS FROM CONVENTIONAL PLANTS

I INTRODUCTION

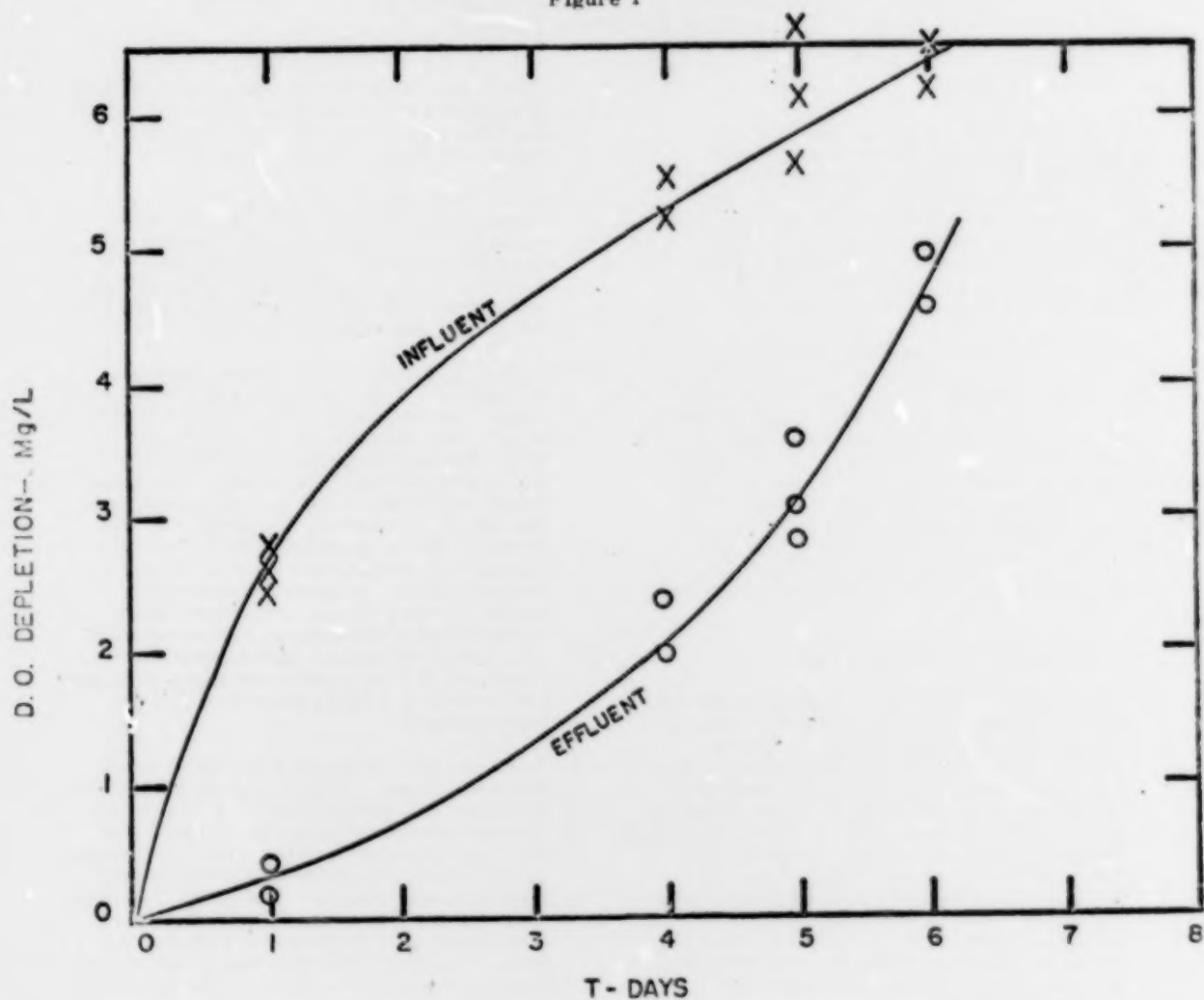
It is an established fact that many of our biological treatment plants produce poor quality effluent. Often, the treatment process itself is mistakenly cited as being inadequate, whereas the true fault lies in not applying known principles and technology efficiently. In other cases, plants perform poorly because they are overstressed out of all proportion to design conditions.

Can we upgrade secondary treatment in general and the activated sludge process in particular? Certainly at many plants we can. In many cases, pollution can be greatly reduced almost overnight by maximum use of existing treatment technology. A properly designed and well-operated activated sludge plant needs no new technology to achieve 90-95% carbon, suspended solids, and coliform removals; what is needed is an awareness of the fundamentals involved and a willingness to pay for and apply all we know.

II PROPER PLANT OPERATION

- A Since the inception of secondary treatment, the major emphasis has been on reducing costs, not reducing pollution. For a weakly concentrated process stream such as wastewater, it is difficult to conceive of any scheme that would be more efficient and economical than aerobic microorganisms. However, there is simply no substitution for time and aeration, and we must be willing to pay for the required treatment volume and blower capacity to allow the biological system to perform efficiently. When we skimp on these two necessities, we have cheaper treatment, but also poorer treatment.
- B All too often, poor treatment is caused due to the failure of city administrators to realize the importance of providing competent, certified plant operators. A plant will not run itself. The difference between a poor and a good operator can often mean 25-30% difference in overall effectiveness. It really defies explanation to invest huge sums in designing and constructing a plant and then turn it over to a chief operator who has no conception of what is involved in waste treatment and what steps can be taken to meet varying problems. Clearly, local, state, and Federal officials have a responsibility to train, attract, and hold good technicians and operators. This implies, again, that we must be willing to pay a fair salary for value received.
- C Once a competent operating staff is assembled, adequate maintenance and replacement budgets must be provided to keep the hardware in good condition. Continuing good operation is not possible when key equipment is constantly down for repairs or becomes antiquated.
- D Proper plant operation should include around-the-clock operation and frequent inspection and adjustment, where necessary, of all controllable process flow rates. Many new instruments are on the market which are applicable to sewage treatment. These instruments can assist the operator not only in monitoring his plant, but also, in some cases, automatically controlling certain key parameters such as sludge recycle rates. Magnetic flow meters, variable speed pumps, rate controllers, sludge blanket indicators, and on-stream pH, dissolved oxygen, and temperature detectors and recorders are types of equipment which are being requested in new plant designs.
- E And last, but certainly not least, proper operation must include adequate laboratory facilities and staff to make the necessary measurements and analyses to document plant performance. Continuous performance records not only assist in the day-to-day operation and control of the plant, but they are valuable reference information when plant expansion is planned. The day is past, too, when BOD and suspended solids measurements will suffice. The BOD test is strictly a procedure to measure the rate at which oxygen is depleted as organic matter is decomposed. It was never intended to indicate the total quantity of organic matter present in a sample nor to measure treatment efficiency. Yet, we use the procedure in both these contexts today.
- 1 Figure 1 shows the daily oxygen depletion of an influent and an effluent. One curve is concave and one is convex which means that the reaction rates of the two bear no relation to one another. Comparing the BOD's of these two samples to obtain a measure of plant efficiency is like subtracting apples from oranges.

Figure 1



2 A better estimate of total organic matter and the oxygen demand present is given by COD or TOC, and unoxidized nitrogen. Figure 2 indicates how these tests can be used to predict the ultimate oxygen demand of waste.

3 In addition to carbon, suspended solids, and nitrogen, phosphorus measurements should become routine practice for laboratory staffs. The subject of phosphorus will be dealt with in greater detail later on today. I should note

Figure 2
Ultimate Potential Oxygen Demand of an Effluent

$$UOD = 2.67C + 4.57N$$

- UOD = Ultimate Oxygen Demand
C = Organic Carbon Content
N = Total Oxidizable Nitrogen
(incl. Organic and Ammoniacal)

Recommended Tests

1. TOC to determine C
2. TKN to determine N

COD may be roughly substituted for
2.67C if TOC Analyzer not available.

before leaving the subject of analytical procedures that the preceding comments on the BOD test are strictly my opinion.

III AIDING OVERLOADED PLANTS

Let's assume we have a competent operator, a good laboratory staff, and modern equipment and controls, yet overall treatment efficiency is still unsatisfactory. If there are no unusual toxic or grossly atypical wastes present, the impairment can usually be traced to one or more of three factors: hydraulic overload, organic overload, and poor final clarifier liquid-solids separation.

A Hydraulic Overload

Figure 3 shows several techniques which may be tried to combat hydraulic overload in certain situations. They are simple but they work.

- 1 The most obvious place to start, particularly in small towns, is to locate and reduce needless sources. Industrial cooling water, for example, should never enter the sanitary sewer system. Many industrial rinsing operations can reduce the volume of rinse water if asked. Ground water infiltration is another possible area which may be attacked.

- 2 Very large interceptors quite possibly can serve as temporary holding tanks during the day and the backup processed through the plant during low nighttime flows.

- 3 Perhaps the most direct and efficient way is to install a surge or equalization tank ahead of the plant. The flow to the plant can be smoothed considerably. If an outpumping scheme is used as shown in Figure 4, the flow can be kept virtually constant over a given 24-hour period. It is well to provide some minimal aeration to keep the waste from going septic. In certain instances by utilizing a floating takeoff and outpumping, a primary settler can also serve as a surge tank, though generally they are smaller than needed.

When all else fails, additional capacity must be provided.

B Organic Overload

Possible remedies for this problem are given in Figure 5.

- 1 A surge tank is useful in diluting strong wastes and evening out the organic loading to the secondary system.
- 2 Industries in smaller towns are usually willing to program their more noxious

Figure 3

Control of Hydraulic Overload

1. Find and reduce needless sources
2. Consider using large interceptors as holding tanks
3. Construct surge tank
 - Fancy
 - Plain
4. Enlarge plant

Figure 4
Surge Tank Sizing

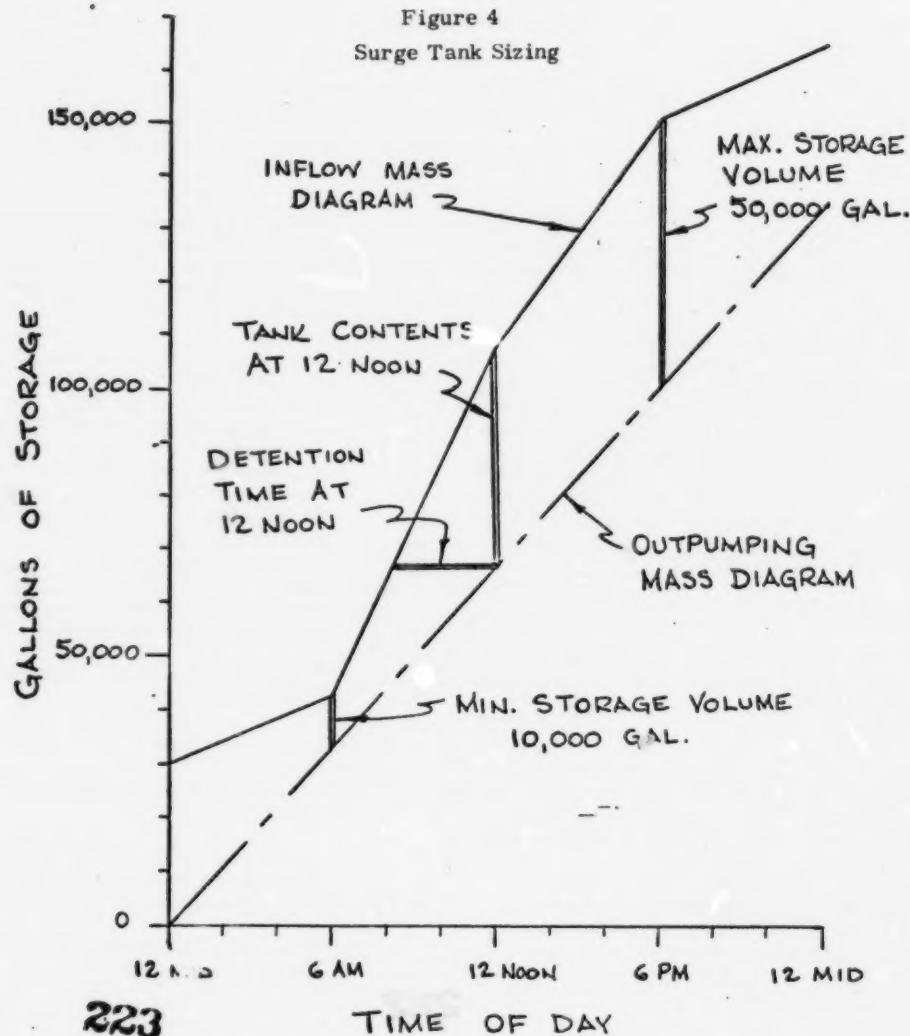


Figure 5

Control of Organic Overload

1. Surge tank to smooth load
2. Have industry program load
3. Program digester supernatant recycle or eliminate
4. Install roughing filter-in line or loop operation
5. Consider two-stage treatment

waste discharges to coincide with lower loading periods of the day.

- 3 Probably the most frequent and upsetting shock load plants have to deal with is digester supernatant. COD and ammonia concentrations of 10,000 - 20,000 and 1,000 mg/l, respectively, are common and together constitute a tremendously high oxygen demand. If the supernatant recycle cannot be broken by separate treatment, it should be returned slowly to the main plant flow stream, not in a slug in a one-hour period in the middle of the day as is often done.
- 4 The recently developed plastic media have a good potential for taking out the bulk of incoming organics when used as a roughing filter ahead of the normal secondary process. If used strictly to control organic overloads, a roughing filter does not require a separate settler.
- 5 Two-stage treatment is worth considering when a high rate system is to be enlarged. The two sludge systems will enhance the possibility of achieving nitrification, and it is unlikely that both sludges will be adversely affected by toxic spills.

C Liquid-Solids Separation

- 1 Physical features that will improve liquid-solids separation are suction-type sludge removal mechanisms, variable speed pumps tied to a sludge blanket indicator or the incoming raw flow meter signal, scum removal equipment, and proper baffling to prevent short circuiting and strong velocity currents.

- 2 Polymers can temporarily keep a bulking sludge from "washing out" gross mixed liquor solids. A drum of polymer and a small dosing pump, if kept in reserve, can get a plant through an upsetting shock load of several days duration. Polymers are stable for long periods of time and are available in powder and liquid form.

IV A RECENT DEVELOPMENT FOR UPGRADING OVERLOADED PLANTS

Union Carbide Corporation has recently completed a research contract with FWPCA which successfully substituted oxygen for air in the activated sludge process. A closed system is employed to achieve high oxygen utilization. Dissolved oxygen is readily maintained in the system even with mixed liquor suspended solids concentrations up to 8,000 mg/l. The necessary aeration volume to achieve efficient organic synthesis and oxidation is reduced to 2-3 hours. Figure 6 shows a schematic diagram of the system and Figures 7 and 8 give treatment data at two nominal aeration periods of 3 and 1-1/2 hours, respectively, which were studied during the contract. This process has very good potential for increasing the capacity and improving efficiency of many overloaded plants in this country without enlarging aeration tank volumes.

V SUMMARY

A summary of anticipated effluent quality and cost data for conventional processes is given in Figure 9. Note that as effluent quality improves, the cost associated with the process rises. Process 6 as shown i.e., primary

Figure 6
SCHEMATIC DIAGRAM OF UNION CARBIDE
OXYGENATION SYSTEM

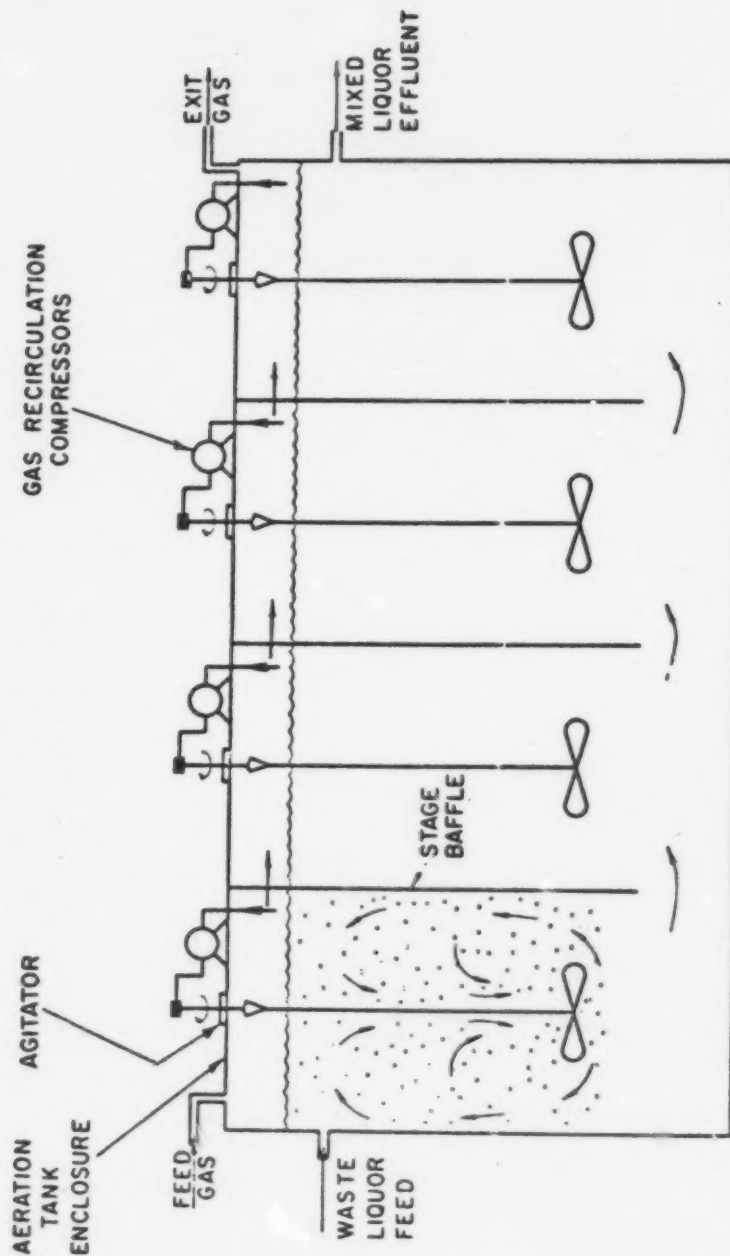


Figure 7

PHASE NO. 3 OPERATION
SUMMARY OF DAILY AVERAGE PERFORMANCE (PRELIMINARY)

<u>Parameter</u>	<u>Air Train</u>	<u>Oxygen Train</u>
Raw Sewage Feed Rate (Mgd)	1.30	1.30
Return Sludge Recycle Ratio	0.25	0.45
Raw Sewage Temperature ($^{\circ}$ F)	69	69
MLSS Concentration (ppm)	3400	6800
MLVSS Concentration (ppm)	2410	4375
Recycle Sludge TSS (ppm)	15400	22050
Mixed Liquor D.O. Concentration (ppm)	0.9	8.6
Clarifier Effluent D.O. Concentration (ppm)	0.0	6.9
TSS of Clarifier Effluent (ppm)	31	16
% TSS Removal	92.5	96
BOD of Clarifier Effluent (ppm)	42	19
% BOD Removal	85	93
COD of Clarifier Effluent (ppm)	147	69
% COD Removal	72	87
Ft ³ Air/Gal. Raw Sewage	3.91	-
Lbs. Oxygen Utilized/Lb. BOD Consumed	-	1.0
% of Feed Oxygen Utilized	-	93.5
Lbs. Dry Solids Wasted	2900	650
Total Oxygenation System Power (HP)	-	18.3
Nominal Aeration Time (Hrs.)	3	3

Figure 8

PHASE NO. 2 OPERATION
SUMMARY OF DAILY AVERAGE PERFORMANCE

Parameter	Oxygen Train
Raw Sewage Feed Rate (mgd)	2.62
Return Sludge Recycle Ratio	0.33
Aeration Detention Time (Hrs.)	1.5 Nominal 1.17 Actual
Raw Sewage Temperature ($^{\circ}$ F)	66
MLSS Concentration (ppm)	7142
MLVSS Concentration (ppm)	4575
Recycle Sludge TSS (ppm)	29600
Sludge Volume Index	35.0
Mixed Liquor D.O. Concentration (ppm)	9.8
Clarifier Effluent D.O. Concentration (ppm)	1.0
TSS of Clarifier Effluent (ppm)	18
% TSS Removal	90.6
BOD of Clarifier Effluent (ppm)	22.9
% BOD Removal	90.1
COD of Clarifier Effluent (ppm)	99.0
% COD Removal	70.0
% Phosphate Removal	22.2
Lbs. Oxygen Utilized/ Lb. BOD Consumed	1.03
% of Feed Oxygen Utilized	92.6
Lbs. Dry Solids Wasted	1804
Total Oxygenation System Power (HP)	16.8

Figure 9

EFFLUENT CHARACTERISTICS AND COST DATA FOR CONVENTIONAL PROCESSES

Process	Total operating cost: \$/mil. gal. 10 mgd plant	Expected Ranges of Effluent Characteristics in mg/l					
		BOD ₅	COD	TOC	SS	TKN	TP
1. PS	60-65	115-150	200-275	65-90	75-100	25-35	8-12
2. PS + TF (high rate)	85-90	40-60	100-150	30-50	30-50	20-30	7-11
3. PS + TF (low rate)	90-95	20-35	55-90	20-30	20-35	15-20	8-12
4. PS + AS (high rate)	95-105	30-40	75-100	25-35	30-35	20-30	7-11
5. PS + AS (conventional)	110-115	15-25	40-70	15-25	20-25	15-20	7-11
6. PS + AS (operated to nitrify)	120-130	10-20	30-60	10-20	15-20	2-4	8-12

Legend

PS - Primary sedimentation
 TF - Trickling filtration
 AS - Activated sludge
 SS - Suspended solids
 TKN- Total Kjeldahl nitrogen as N
 TP - Total phosphorus as P

Assumed Raw Wastewater Quality

BOD₅ : 175-225 mg/l
 COD : 325-450 "
 TOC : 100-130 "
 SS : 200-250 "
 TKN : 30-40 "
 TP : 10-15 "

settling followed by activated sludge operated to nitrify, represents about the maximum efficiency that can be extracted from biological treatment alone.

This outline was prepared by R. C. Brenner, Research Sanitary Engineer, Biological Treatment Research Program, Advanced Waste Treatment Research Laboratory, OWP, EPA, Cincinnati, OH 45226.

SECTION V

Special Management Considerations Integrated Management includes consideration of plans, construction, performance and ability to convince the public that adequate finance for it is necessary. Selected approaches are reviewed.

	<u>Outline Number</u>
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REVIEW OF PLANS AND SPECIFICATIONS

I MAJOR TOOLS OF AN EFFECTIVE WATER POLLUTION CONTROL PROGRAM

- A Establishment of Water Quality Standards
- B Research & Development
- C Regional Planning of Sewerage Facilities
- D Enforcement Actions as Required
- E Design and Construction of Waste Treatment Facilities
- F Effective Operation and Maintenance of Waste Treatment Facilities

II OBJECTIVES OF PROJECT DESIGN REVIEW

- A Determination that the entire project reflects acceptable engineering practice and judgement, conformance with requirements of applicable intra and interstate Water Quality Standards and Federal Enforcement Actions and reflects the implementation of the regional sewerage facility plan where the plan has been developed.
- B Since public funds at the local, state (where there is a State Construction Grants Program) and Federal level are to be used, it is imperative that we obtain the maximum of treatment facilities for each dollar spent.
- C Waste Treatment Facility must include the components to accomplish the following:
 - 1 Reliability of treatment to provide the required treatment efficiency at all times.
 - 2 Flexibility of operation. The operator must have the necessary piping, valves, meters, controls, tankage and equipment to adjust his process to meet

changing conditions or unforeseen variations in the quality and quantity of waste to be treated.

- 3 Process, plant layout and equipment used must be capable of producing an effluent to meet the requirements of the water quality standards.
- 4 Safety and ease of maintenance.

III AIDS FOR TECHNICAL REVIEW OF PROJECT

- A The following reference manuals are of value in the review procedure:
 - 1 Recommended Standards for Sewage Works (Ten States Standards)
 - 2 The Water Pollution Control Federation Manual No. 8 entitled "Sewage Treatment Plant Design".
 - 3 The applicable state rules and regulations
- B Application of Experience

We should apply the benefit of our past experiences regarding deficiencies in design, construction, operation and ease of maintenance.

IV TECHNICAL REVIEW OF WASTE TREATMENT FACILITIES

The FWPCA Construction Grants Program is responsible for the technical review of engineering reports, plans and specifications, inspections during construction and initial operation and subsequent evaluation of the operation and maintenance of the facilities after they have been completed. As a result of this experience, the Construction Grants Program in the Northeast Region has prepared a guide entitled "Technical Review of Waste Treatment Facilities"

(copy attached). This is used to outline some of the design considerations which either are not covered adequately by the standard design manuals or which we believe require particular emphasis. The remainder of this discussion will relate to some of the more important subjects covered in the attached guide.

A Review of Engineering Report

The engineering report should be reviewed to determine that the project will result in, or will be part of, an operable treatment works which will abate, control, or prevent pollution.

B Review of Plans and Specifications

The plans and specifications must be reviewed with particular attention given to the following:

- 1 Process and hydraulics
- 2 Plant layout and piping
- 3 Solids handling
- 4 Safety features

This outline and attached "Technical Review" were prepared by Rocco D. Ricci, Chief, Construction Grants Program, NY-NJ-Del, FWPCA, Northeast Region, Edison, NJ.

TECHNICAL REVIEW OF WASTE TREATMENT FACILITIES

Review of Engineering Report

The engineering report for each project is reviewed by the Construction Grants staff prior to the Federal grant offer. This review must establish compliance with the following requirements:

- 1 A determination that the project will result in, or will be part of an operable treatment works which will abate, control, or prevent water pollution. All existing interceptors, pumping stations or treatment facilities must have adequate capacities to properly convey or treat the additional wastes to be collected from an extension of the intercepting system.
- 2 The degree of removal and provisions for chlorination must conform with the requirements of interstate water quality standards and Federal enforcement conference findings, if applicable; Federal comprehensive river basin plans and the State water pollution abatement program plan.
- 3 The policy of the Federal Water Pollution Control Administration prohibits discharge of any settleable solid waste to any watercourse. This policy also requires that the solids once removed from the plant flow must not be returned in the original or changed state to the watercourse. This, of course, includes prohibiting the return of grit basin solids, clarifier sludge, digester sludge, filter cake, incinerator ash (including fly ash), activated sludge or any other solids.
- 4 Adherence to the intent of the Federal Water Pollution Control Act requires that we continue to seek the best possible degree of treatment for each treatment works. Therefore, we must continue our attempts to delete all plant by-passes and overflows that are

not absolutely necessary and seek operational flexibility through the provision of alternate treatment units, standby power and any other means to insure the reliability of operation and continual treatment of the waste waters.

- 5 The cost for the waste treatment facilities must be reasonable. The need for excessive per capita design flows for treatment facilities to serve an existing collection system must be well documented. This documentation is to include a study of the nature and source of the infiltration or storm water connection problems in the system, as well as an estimate of the cost of the various alternatives to correct the situation.
- 6 The project should be compatible with regional sewerage facility planning. The municipalities should be required to join in cooperative regional facilities wherever feasible in order to reduce construction costs and operation and maintenance expenses.

Review of Plans and Specifications

The plans and specifications must be reviewed and approved by the FWPCA before the project is advertised for bids. This review is made to determine that the project reflects acceptable engineering practice and judgment, and conformance with the requirements of the Federal Water Pollution Control Administration as outlined above.

The most important determination is whether the plant will perform in an acceptable manner. To be acceptable, the plant must provide for reliability of operation as well as efficiency of operation. Since we are entrusted with the expenditure of public funds, we must obtain the maximum amount of treatment facilities for each Federal dollar expended.

Therefore, the following items are given special attention during the plan review by the Construction Grants staff of FWPCA.

Process and Hydraulics

- 1 The plans and specifications are checked to be certain that the process is complete and will provide the necessary flexibility of operation to obtain the highest degree of removal. The flow diagram is checked against the general piping arrangement to establish the fact that the plant design conforms with the necessary features of the process flow pattern. This includes such considerations as the return and measurement of sludge in the activated sludge process, variable recirculation capacity for trickling filter plants, and the possibility of by-passing the primary tanks in the conventional activated sludge process to permit the introduction of raw waste into the aeration tanks.
 - 2 The plant hydraulic profile must be shown in the engineering report or plans. The flow must pass through the treatment facilities without topping the structures, short circuiting or submerging the wiers. The hydraulic gradient is to permit flow into the receiving stream during periods of flood stage. All structures should be constructed above flood stage of the receiving stream.
 - 3 The ability of the receiving stream to assimilate the effluent from the treatment plant must be considered. The effluent from even a secondary treatment plant is not to discharge into a swamp or similar stagnant area. Consideration must be given to the design of tertiary treatment where it will be necessary for the plant effluent to discharge into a stream bed which is dry during most of the year.
 - 4 Whenever a plant will discharge to shellfish waters, it is necessary for FWPCA to consult with the Shellfish Program of the U.S. Public Health Service.
- The following comments have been submitted to this office by the Shellfish Section of the U.S. Public Health Service. We have been requested to consider these items in the design of new facilities which will affect the shellfish waters:
- a All pumping stations should have auxiliary pumping units to prevent by-passing of inadequately treated sewage in the event of pumping failure.
 - b An auxiliary power source should be provided to insure that all treatment facilities continue to operate in the event of a commercial power failure.
 - c Dual chlorination units should be provided. Facilities to register and record chlorine residual values should be installed.
 - d Automatic sound alarms, operating independently of treatment plant power, should be installed to give warning of high water, power failure or breakdown. Such an alarm system should extend by wire to the police station or other location where assistance can be obtained in an emergency if the plant is not attended 24 hours a day.
 - e All unit drains and overflows should return to the head of the plant.
 - f For a combined sewer system, adequate holding tanks, lagoons or other facilities should be considered to prevent flooding of the plant and discharging inadequately treated sewage.
 - g The discharge of sludge or any solids to the river should not be permitted. All sludge drying beds should be well above the high water level of the river.
- 5 As indicated previously, all complete plant by-passes and overflows that are not absolutely necessary must be eliminated. Whenever it is determined

that the by-pass is necessary because of excessive infiltration or storm water connections to a separate collection system, the engineers and community must indicate the steps that are being taken to eliminate or curtail this flow into the collection system. The discussions relating to the possible elimination of a plant by-pass should include a determination of the past history of power outage and whether consideration has been given to provide standby power wherever there is a recorded high frequency of power failure.

- 6 The process and equipment specified cannot be of an experimental nature to receive Federal participation under the Federal Water Pollution Control Act unless the process or equipment is first approved by the State. The specifications must include sufficient performance guarantees, including the replacement of the treatment facilities with more conventional units, should the experimental facilities fail to perform to the satisfaction of the State Agency and FWPCA.
- 7 Where a treatment plant is to receive wastes from industries, we must obtain information regarding the industrial waste ordinances and the characteristics of the waste to be treated.
- 8 A skimming device and baffle must be furnished on secondary clarifiers to remove floating solids.
- 9 Wherever it is necessary to convert a standard rate trickling filter to a high rate trickling filter, the following items must be evaluated and may require modification or removal and replacement with new material:
 - a Sizing of stone
 - b Ability of the underdrainage system to carry the high hydraulic loading and at the same time permit adequate flow of air in the underdrainage system.
 - c The distributor must be capable of carrying the higher rates of flow.

10 When additions and alterations are to be made to an existing plant, the following provisions must be made part of the specifications:

- a During construction, raw sewage must not be permitted to discharge to the stream without a minimum of primary treatment and chlorination.
- b The contractor must provide a construction schedule to indicate how raw sewage by-pass will be averted.

Plant Layout and Piping

- 1 Duplicate units are recommended. This is a necessity in the larger plants to provide flexibility of operation without by-passing process steps during periods of unit maintenance. Drains should be provided on all of the tanks where practical (at least a sump) to permit dewatering of all units and the necessary maintenance of these units. Unit drains must not discharge into the outfall sewer.
- 2 The chlorine contact tank should be designed with duplicate compartments to permit draining and cleaning of individual compartments. Each compartment must be provided with a drain to return solids to the plant process, not to the outfall. Wherever practical, the floor should be sloped to the drain connection. Experience has clearly indicated the desirability of making it reasonably easy for the operator to dewater this unit and clean out the accumulated solids which would otherwise lie on the floor of the tank, decompose and eventually cause a degradation of the quality of the effluent. Baffles must be provided to prevent the discharge of floating material.
- 3 Piping and connections must not allow the discharge of sludge or any other solids, including incinerator ash, to the outfall sewer.

- 4 All supernatant, drainage from drying beds and any other overflow from thickening units, etc., must be returned to the treatment units and must not flow into the effluent stream without treatment.
- 5 The potable water supply must be protected to eliminate the possibility of contamination by cross-connections with the sewage or sludge. This protection includes backflow prevention prior to any connections to yard hydrants in the treatment plant.
- 6 Interior process piping should be identified by color coding.
- 2 Wet wells of pumping stations must be provided with positive means of ventilation.
- 3 The plant should be enclosed in an adequate fence.
- 4 Railing should be provided wherever it will contribute to safer operation of the facility.

General Features

- 1 Slide gates should not be used when a watertight control is necessary.
- 2 Projects for intercepting sewers must include the following in the plans and specifications:
 - a Infiltration or exfiltration tests and allowable limits
 - b Bedding specifications and details
 - c Jointing specifications
- 3 Equipment with a high noise level (such as compressors and centrifuges) should be enclosed in separate rooms.
- 4 An adequately equipped laboratory must be provided.

Solids Handling

- 1 Complete information must be furnished regarding the ultimate methods of sludge disposal. This information must include an evaluation of the adequacy of drying beds, control exercised by the local regulatory agencies over areas of liquid sludge disposal to insure that this method will not cause pollution of a water course, reliability of operation of the vacuum filter units or any other method of ultimate destruction of waste solids.
- 2 Extended aeration plants must be furnished with sludge holding tanks for wasting excess sludge. Polishing lagoons are also recommended where practical.

Safety Features

- 1 Chlorine facilities must be provided with powered ventilation and heating. The switch for the fan should be located on the outside of the door of the facility.

FINANCING CONSTRUCTION OF SEWERAGE SYSTEMS

I INTRODUCTION

- A The volume of municipal bonds issued in 1967 reached an all time high of \$14.2 billion or an increase of 28.4 percent from the previous high in 1966. The Joint Economic Committee projects average borrowings for the years 1969-73 at \$18.6 billion.
- B Cost of waste treatment and sewer systems for local government for the period 1969-73 is estimated at \$14.9 billion or an annual average of \$2.98 billion.
- C To comply with the Water Quality Act of 1965, municipalities will require a volume of bonding at more than 3.6 times the present level of spending for this purpose, which would represent 16.1 percent of the estimated average bond market for the years 1969-73.
- D By steadily increasing the rate of interest it is theoretically possible that the increased demands upon the municipal bond market could be absorbed. However, at the higher rate of interest the economic feasibility of the desired projects may be jeopardized, statutory rate limitations may be encountered, and a general reluctance by the borrower to pay such rates may be anticipated - any one event may effect a delay in the achievement of the FWPCA program in the scheduled time period.
- E Historically, financial institutions have been reluctant to purchase a large percentage of sewer bonds. As the National program gains momentum the buyers will be able to fulfill their demands with the stronger credits, leaving the smaller or weaker communities unable to borrow or be forced to pay a relatively high rate of interest.

II BASIC PLANNING FOR A SEWERAGE PROGRAM

A Comprehensive Improvement Program

A community should develop a comprehensive program for pollution abatement encompassing current and future demands. This in turn would be the guideline for proper financial planning.

B Retention of Technical Experts

1 Consulting Engineer

The community should retain a consulting engineer to make a master plan for sewers and waste treatment facilities. This plan will determine the possible solutions to the engineering problems and the most economical solutions in terms of long-range planning.

2 Financial Advisor

The community should immediately employ a financial advisor to review its planning schedule and to recommend a financing program. A financial advisor will usually assist the community in all steps necessary for the sale of bond including providing bond counsel with the details to be included in the proceedings, making suggestions in drafting the bond ordinances, prepare an Official Statement (prospectus) on the community and the project for submission to bond rating agencies, prospective underwriters and purchasers of its bonds.

3 Bond Counsel

In order for a community to issue bonds it is necessary that a nationally recognized municipal bond attorney render a legal opinion to the bond purchaser that the bonds are valid obligations of the issuing body.

C Enabling Legislation

Legal restrictions at the State and local level are a major obstacle to borrowing for required capital outlays. The primary restrictions upon the States are constitutional debt limitations and referendum requirements for incurrence of debt. Interest rate limits and prescribed terms and conditions by which the obligations may be issued also restrict the ability to borrow.

D Community Credit Quality

The ability of a community to successfully achieve its program will depend upon many separate factors in the community that serve as collateral and security for the borrowed funds.

1 Character of the Community

- a Historical background
- b Debt paying ability
- c Activity on which the community's prosperity is dependent
- d Character of the officials
- e Strength of the local banks

2 Debt

- a Debt trend
- b Schedule of debt service requirements and relationship to total annual revenues
- c Amount of overlapping debt

3 Source of Payment

- a Tax limitations
- b Priority of claims
- c Revenue collections
- d Tax rate

III CURRENT METHODS OF FINANCING SEWERAGE SYSTEMS

A Pay-as-you-go Financing

This method is generally not adaptable to financing sewerage systems because of the need to create large surpluses or reserves before construction can begin.

B General Obligation Bonds

A general obligation bond is secured by the issuer's pledge of its full faith, credit and taxing power for the payment of the bond. General obligation bonds for sewerage facilities represented 73.4 percent of all obligations issued for this purpose in 1966.

1 Special Assessment Bonds

These bonds are payable from special assessments against those who benefit from the facilities constructed; the great majority of this type of issue is additionally secured by a pledge of full faith, credit and taxing power, so that

they are general obligation bonds.

2 Limited Tax Bonds

Secured by the issuer's full faith, credit and taxing power, but taxing power is limited to a specified maximum tax rate.

C Revenue Bonds

Used for "self-liquidating" projects where service is provided on a use or service charge basis. The service charge provides all the revenues for the project, including construction, operation and maintenance cost; principal and interest payments; and a coverage factor of from 1.25 to 1.50 percent.

D Regional District or Authority Bonds

Such arrangements usually occur when there are advantages to building a single facility to treat the wastes of several communities. At least three-fourths of the states now have enabling legislation or authorization for interlocal contracting and agreements covering sewerage facilities. Generally district bonds are of a general obligation nature while authority bonds are secured by revenue charges.

IV PROCEDURAL OUTLINE FOR SALE OF BONDS

The manner in which an issuing body prepares for the sale of bonds will influence the rate of interest on its debt and attractiveness to investors.

A Financial Policy

Extreme care is called for in the issuance of municipal bonds since it creates a large inflexible obligation for a long term of years.

B Choosing the Market

Many factors will affect the time when bonds should be sold--current supply and demand, calendar of future offerings, and competitive issues. Best to consult with a financial advisor.

C Planning the Issue

1 Negotiable Instruments

Municipal bonds should be negotiable instruments so that they will be enforceable in the hands of a holder.

2 Legal Opinion

Each municipal bond issue must be approved by an attorney whose legal opinions satisfy the market where the bonds are sold.

3 Rates of Interest

No maximum rate of interest need be set; if there is a legal maximum it should be stated. Let the underwriters establish the rate or rates.

4 Maturity Schedules

Bonds should be issued to mature over the useful life of the improvements. Some states have legal limits on the maximum life of a bond issue and the schedule of annual payments. Bond scheduling must contemplate propensity to repay.

5 Conventional Requirements

- a Bonds should be dated as near as possible to the delivery date.
- b Bonds should usually be issued in denominations of \$1,000 or \$5,000.
- c Interest should be paid semiannually.
- d If bonds are serial, each annual maturity should be in multiples of five thousand or ten thousand dollars.
- e The bond owner should have the privilege of registering his bonds as to principal only, or as to both principal and interest.
- f Where the bonds have a wide market, principal and interest should be payable in a large financial center.

6 Advertising

A proposed sale should be publicized in local newspapers as well as in the DAILY BOND BUYER, a nationally circulated paper among municipal bond dealers.

7 The Official Statement or Prospectus

The municipality which sells bonds must be prepared to give comprehensive data about the community, its economic background, and its financial situation. The prospectus should be sent, without request, to the investment bankers and

other institutions that are interested in the municipality's securities and to a select list of large investors. Rating and information agencies should also be given this data.

8 The Bond Sale

General Obligation Bonds should usually be sold at public sale on the basis of competitive bids. However, in some cases, particularly in the case of revenue bonds, private negotiations may be advantageous. All bids should be on a basis of the lowest net interest cost to the community. Bonds should be delivered at the earliest practical date after the sale.

V NEW FINANCING CONCEPT

Several State and local governments faced with large capital outlays for pollution abatement are developing new bonding techniques to ease the administrative, technical and financial burden.

A New York State Pure Waters Authority

Created to assist local governments, upon request, in the planning, financing, construction, operation and maintenance of sewerage systems.

1 General Powers of the Authority

- a Construct, operate and maintain sewerage facilities for a community.
- b Make loans to a community for the construction of sewerage systems.
- c Provide sewerage services to a community with facilities owned, constructed, operated and maintained by the Authority.
- d Provide technical advisory services to a community.

B Ohio Water Development Authority

Provides the same services as the New York State Pure Waters Authority but is available to assist industry in providing required facilities.

C Nebraska Clean Waters Commission

Provides financing of sewerage facilities for local communities.

D Omaha Pollution Control Corporation

Excellent example of a community which developed a financial and technical program that allowed it to create an asset out of a pollution liability that almost paralyzed its major industry.

VI SOURCE OF FUNDS

Among the holders of municipal securities at the end of 1965, the largest were commercial banks, personal trust funds, fire and casualty insurance companies, and "individuals and others". Altogether such holders accounted for 83.3 percent of total holdings of \$100 billion.

VII WASHINGTON SUBURBAN SANITARY DISTRICT

The District covers 520 square miles in Maryland, bounds the District of Columbia on three sides, and represents approximately 85 percent of the population of Montgomery County and Prince George's County. District provides water supply, storm water, and sewage disposal services for said counties. The actual sources of revenue for payment of debt services vary with the purpose for which bonds have been issued.

A General Construction Purposes

District is required to levy a tax which together with front foot benefit charges will be sufficient to meet maturing principal and interest.

B Storm Drainage

The District includes in its ad valorem rate a rate for service thereon.

C Water Supply

Service charges for water sufficient to pay principal, interest, operation and maintenance costs of the system.

D Sewage Disposal Bonds

Sewer use charge to connected properties sufficient to pay principal, interest, operation and maintenance costs of the disposal system.

E Incinerator Bonds

Payable from charges for refuse collection and disposal, but in the event of any deficit, from water system earnings.

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PUBLIC RELATIONS RESPONSIBILITIES

I INTRODUCTION

Pollution is in a large measure a public relations problem and as such it involves all in dedication to being a good citizen, a good neighbor, and to the philosophy of the public's best interests.

Men and women in the water pollution control field, operators, consultants, industrial plant managers, manufacturers, public works directors, city councilmen, and any one of the many people concerned with wastewater management have a stake in this public relations task.

II AVENUES OF APPROACH

An informed public is better equipped to make decisions based on fact and reason than upon emotion. Good public relations should not seek to change facts. However, it can present them in the best frame of reference for clear understanding and at a time when they will be best received.

A Direct Methods

Some of the direct methods commonly used are printed material, telephone calls, notices in mailing of water and tax bills, a periodic newsletter and personal calls (direct contacts).

It is essential to respond immediately in some way, by investigation, by corrective actions or by indication of where action can be expected. Courteous response should be given to all requests that may be related to the department's field of action and knowledge.

B Indirect Methods

There are many indirect avenues which can do the job of informing the public. These include the mass news outlets, local and national (weekly, biweekly or daily newspapers), radio, television, and state and national trade publications.

Material submitted to the news outlets should be handled in a manner acceptable to them, as well as useful to the person initiating them.

C Community Affairs

Attendance at all meetings of local governing bodies and taxpayers is important.

The value of close contact with local school administrators and PTA groups for opportunities to participate in their programs is important. Arrange for plant tours and visits. If funds are available, use motion or still pictures, or slide talks.

If an individual report of the activities of a department is published, enough copies should be prepared so that the report can be given the widest possible circulation. When reports are sent, it is wise to request copies of theirs.

Be a joiner! Encourage others to be active in organizations within the community, state and nation that are related to the work being done, or in some way have an interest in government or taxpayer problems. These include engineering and trade associations, fraternal groups, and neighborhood groups. Get yourself known, if you hope to do a good job of informing the public of your work and activities.

III PUBLIC RELATIONS TOOLS

Good public relations depend more on an individual approach to a problem or objective rather than on formalized procedures.

A News Releases

The news release is probably the most commonly used method of getting information to various news outlets such as newspapers, magazines, radio, television, wire services and news syndicates.

1 Basic news

If data are needed to elaborate on a news story, a supplementary sheet giving details may be included.

2 Speech story

This concerns itself with who (made the speech), what (was said), why (the speech was made), where (it was made), and when (it was made).

Public Relations Responsibilities

B Photographs

A photograph, with a short descriptive caption, can itself be a news release.

A "photo check list" should be made prior to taking photos for use in the public relations field.

C Advertisements

One aspect of public relations frequently ignored is advertising. If funds are available, the best available, avenue of approach is paid advertising.

D Speeches

Nothing can replace the essentials of a good talk.

E Bulletins and Newsletters

Keeping your own people informed, whether they are located in a single office, or scattered in several locations, is as important as informing the public of your water pollution control activities.

F Exhibits

It is a good investment in public relations to have displays in the best available manner. A display can be used in conjunction with a meeting of the town board, similar offices or at local centers which offer varied traffic both local and transient.

IV WORKING DIRECTLY WITH THE PUBLIC

The desired image must be established over a period of time through hard work and intelligent approaches to a variety of situations and operations.

A Facing the Public

Daily contacts between personnel and members of a department and those of local government and the public are important toward good public relations.

B Telephone Manners

Courteous and established procedures for handling telephone calls are an important part of public relations.

C Complaints

The handling of complaints, whether received by telephone, mail, hearsay, or

referral by other departments and personnel, should be prompt and efficient.

D Mail

Care should be taken that all correspondence is neat, without messy erasures or misspelled words.

E Schools

An audience that is important to reach consists of local elementary and secondary schools and universities. A continuing education of the community's youth assures a constant interest and understanding through the years ahead.

F Community Activities

These include seminars, workshops, go-see tours, adult education series, film and speakers' bureaus.

V EFFECTIVE CITIZEN ACTION - PUBLIC SUPPORT

Effective participation by citizens in water pollution control decisions involves a continuing effort particularly in the local community.

VI SUMMARY

Public relations is a continuing activity. This effort of communicating with the public is as essential as perhaps it ever will be.

The best way to influence the public and public officials is to ORGANIZE, DRAMATIZE, and RECOGNIZE. Organize--for an effective voice. Dramatize--to obtain public support. Recognize--accomplishment. People will do things for recognition they would not do for any other reason.

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GLOSSARY - WASTEWATER TREATMENT TECHNOLOGY

This is a selected list containing the key ideas of terms likely to be encountered in treatment technology.

ABSORPTION - The taking up of one substance into the body of another.

ACRE FOOT - A volume term referring to that amount of liquid 1 acre in area and a depth of 1 foot. 43,560 cu.ft.

ACID - Most commonly refers to a large class of chemicals having a sour taste in water, ability to dissolve certain metals, bases or alkalies to form salts and to turn certain acid-base indicators to their acid form. Characterized by the hydrated H^+ ion.

ACTIVATED SLUDGE - A process used for purification and stabilization of wastewaters by mixing of the solids concentrate from previous contact with raw or settled wastewaters under turbulent oxygenating conditions for sufficient time to permit transfer of nutrients to the solids phase, partial biodegradation and clarification of the water before discharge.

ADSORPTION - The taking up of one substance upon the surface of or interface zone of another substance.

ADVANCED WASTE TREATMENT - Renovation of used water by biological, chemical or physical methods that are applied to upgrade water quality for specific reuse requirements. May include more efficient cleanup of a general nature or the removal of components that are inefficiently removed by conventional treatment processes.

AERATION - The operation of adding oxygen to, removing volatile constituents from, or mixing a liquid by intimate contact with air.

AERATION PERIOD - A theoretical time usually expressed in hours equal to the volume of the tank divided by the volumetric rate of flow.

AEROBIC - A condition characterized by an excess of dissolved oxygen in the aquatic environment.

For more scientific definitions or unlisted terms, consult the list of references at the end of the glossary.

AEROBIC BACTERIA - Organisms that require dissolved oxygen in the aquatic environment to enable them to metabolize or to grow.

AGGLOMERATION - An action by which small particles gather into larger particles that are more readily separated from the liquid by sedimentation or other means. May be the result of biological, chemical or physical factors.

AIR LIFT - A pump consisting of a vertical pipe immersed in a liquid into which air is mixed to reduce specific gravity of the air-liquid mixture. The net effect is to raise the liquid level in the discharge pipe.

ALGAE - Primitive plants, one or many celled, usually aquatic and capable of growth on mineral materials via energy from the sun and the green coloring material, chlorophyll. Generally considered as the primary source of food for all other organisms.

ALKALINITY - A term used to represent the sum of the effects opposite in reaction to acids in water. Usually due to carbonates, bicarbonates and hydroxides; also including borates, silicates and phosphates.

AMPEROMETRIC CHLORINE RESIDUAL - A means of determining residual available chlorine with phenyl arsene oxide (PAO) titration using current response as an indicator of equivalence. For wastewater, the PAO preferably is used in excess with iodine backtitration.

ANAEROBIC - A condition in which dissolved oxygen is not detectable in the aquatic environment. Commonly characterized by the formation of reduced sulfur compounds from the use of bound oxygen from sulfates as an hydrogen acceptor.

ANAEROBIC BACTERIA - Organisms that can metabolize and grow in the absence of dissolved oxygen. Their oxygen supply is obtained from the bound oxygen such as in sulfates, carbonates, or other oxygen-containing compounds.

ANION - A negatively charged ion in water solution. May be a single element or a combination of elements, such as the Cl^- ion in a water solution of NaCl (common table salt) or SO_4^{2-} ion in a sulfuric acid solution.

ASSESSMENT - A legal financial obligation of the property owner in an irrigation, water, drainage or sanitary district, created for the purpose of financing the construction and operation of facilities required to protect and enhance public benefit within the district.

ATTACHED GROWTH - Plant or animal growth that tends to seek a solid surface for a point of attachment from which to grow, in contrast with free-swimming or suspended organisms.

ATOM - An extremely small unit or particle of an element consisting of a positively charged nucleus and one or more negatively charged electrons. Atoms of different elements are different in mass and the number of electrons. Electrons may be located in the nucleus or externally. The external electrons determine chemical combining power.

ATOMIC WEIGHT - A relative mass of an atom of an element compared to carbon-12. May be expressed in grams (g), pounds or other consistent weight units when used for process control.

AVAILABLE RESIDUAL CHLORINE - Generally refers to that part of the chlorine that will react with ortho toluidine or amperometric tests and exhibits significant germicidal activity.

AWWA (AMERICAN WATER WORKS ASSOCIATION) - An organization composed of individuals engaged in research, design, operation and control in the advancement of knowledge related to potable water supply

BACTERIA - Primitive organisms having some of the features of plants and animals. Generally included among the fungi. Usually do not contain chlorophyll, hence commonly require preformed organic nutrients among their foods. May exist as single cells, groups, filaments, or colonies.

BACTERIACIDE - Any component that will kill or destroy bacteria.

BACTERIOSTATIC - A condition during which the normal metabolic functions of bacteria are arrested until favorable conditions are restored.

BACTERIOLOGY - See Microbiology.

BAFFLE - A deflector or check such as a vane, guide boards, plates, grids, grating, or similar devices used to control the flow distribution or velocity of liquid in a channel or basin.

BAR RACKS (SCREENS) - A coarse screen usually consisting of bars spaced with 1 to 5 inch openings to trap roots, branches, rocks, rags, and other large materials that may be encountered in the flow of a channel or conduit.

BASE - A foundation, plate, natural or engineered support upon which a structure, channel, machine, or other device is mounted.

Chemical: A base includes a large variety of chemicals opposite in reaction to acids (alkali).

BED LOAD - Generally refers to the oxygen demand requirements of benthic deposits, sludge, muck, attached growths, moving materials, living or dead that are exerted upon waters as a result of bottom or boundary dynamics.

BENTHIC DEPOSIT (BENTHOS) - Refers to the accumulated deposition of cell mass living or dead that collects at the bottom of a stream impoundment where velocity or catchment permits.

- BIO-CHEMICAL** - Resulting from the combined activities of biological and chemical transformations. Usually measured in terms of the ensuing chemical changes.
- BIODEGRADATION** - The stabilization of wastewater contaminants by biological conversion of pollutants into separable materials at a higher oxidation state.
- BIO FILTER** - See Trickling Filter.
- BIOLOGICAL PROCESSES** - Activities of living organisms to sustain life, growth, and reproduction. Commonly the processes by which organisms degrade complex organic material into simpler substances at a higher oxidation state to obtain energy for life processes and growth of new cell mass.
- BIOLOGY** - The science and study of living organisms, characteristics and behavior.
- BOD** - Biological or biochemical oxygen demand. A test for estimation of wastewater polluting effects in terms of the oxygen requirements for biochemical stabilization under specified conditions and time.
- BRIDGING** - A condition in which particulates or solids concentrates that would normally seek the lowest level of a restricted channel or basin, tend to hang up on sidewalls. The bridged material commonly may settle again with vibration, agitation, a change in flow direction, or increased flow velocity.
- BTU (BRITISH THERMAL UNIT)** - That amount of heat that will raise the temperature of one pound of water one degree Fahrenheit.
- BUFFER ACTION** - An action exhibited by certain chemicals that limits the change in pH upon addition of acid or alkaline materials to the system. In surface water, the primary buffer action is related to carbon dioxide, bicarbonate and carbonate equilibria.
- BULKING** - A condition, usually related to activated sludge processing, in which the sludge solids separation from the liquid is inhibited.
- Rapid growth, filamentous organisms, and certain other factors that are but vaguely understood, tend to produce a low density thin sludge that settles very slowly and has limited compactability.
- BURNER, WASTE GAS** - A device for burning the excess gas from sludge digestion.
- CALORIE** - That amount of heat required to raise one gram of water one degree Centigrade, or Celsius.
- CARBOHYDRATES** - Naturally occurring compounds consisting of carbon, hydrogen and oxygen, that are considered as energy foods and precursors of proteins and fats in the natural food chain.
- CATALYST** - A substance that influences the rate of chemical change but either remains unchanged during the reaction or is regenerated thereafter. Generally applies to acceleration of reaction rates.
- CATCH BASIN** - A chamber, well or other enlargement of a channel, designed to retain grit and detritus below the point of liquid overflow.
- CATION** - A positively charged ion in water solution. May be a single element or a combination of elements, such as Na^+ in a water solution of NaCl (common table salt).
- CENTI** - An expression used to indicate 1/100 of a given standard unit centimeter (cm), 1/100 meter.
- CENTIGRADE** - A temperature measurement scale in which the freezing point of pure water at sea level is designated as 0°C and the temperature of boiling water is designated as 100°C . This is more properly termed the Celsius scale.
- CENTRIFUGAL PUMP** - A pump consisting of a rotating impeller within a casing having an inlet near the center and an outlet or discharge at the tip of the impeller where centrifugal force is greatest.

CENTRIFUGE - A device for separation of solids or liquids of different densities by rotational energy; heavy materials move outward, less dense materials move toward a central take-off port.

CHANNEL - A natural or artificial waterway which continuously or periodically contains flowing water. A connecting link between two bodies of water with a definite bed and sidewalls to confine the flow.

CHANNELING - A condition in which certain portions of the flow within a channel or basin tend to seek a more limited distribution than that resulting from the confining bed or sidewalls, i.e., the flow may channel along the top, bottom or mid channel depth due to density, temperature, or some form of obstruction to uniform cross sectional flow.

CHECK VALVE (FLAP GATE) - A device to control flow in a pipe or channel limiting it to one direction. Commonly a gate hinged at the top that is limited in movement by a seat in a near vertical position so that it can open for flow in one direction but closed by reverse flow.

CHEMISTRY - A science that deals with the composition and characteristics of substances and their behavior, i.e., the transformations that they undergo.

CHLORAMINES - Products of the combination of chlorine and ammonia. Commonly classified as combined available chlorine.

CHLORINE - A greenish yellow gaseous element having strong disinfecting and oxidizing properties in water solution. It is commercially available as compressed gas, liquid, or in combined form as a powder. It is highly toxic and irritating to skin, eyes, and lungs in significant concentrations.

CHLORINATION - The application of chlorine to water or wastewater for the purposes of disinfection, oxidation, odor control, or other effects. Pre-chlorination - before treatment; post-chlorination - after treatment; in-process chlorination - during treatment.

CHLORINATION CHAMBER - A basin or tank where chlorine is applied to the liquid.

CHLORINE TEST - Commonly refers to one of two methods separately listed: see Ortho tolidine test; see Amperometric test.

CHLORINE DEMAND - The difference between applied chlorine and residual available chlorine in aqueous media under specified conditions and contact time. Chlorine demand varies with dosage, time, temperature, nature and amount of the water impurities.

CHLORO ORGANIC COMPOUNDS - A broad group of compounds containing chlorine, carbon, hydrogen and sometimes other elements. Generally originating from or associated with living or dead organic materials. This group shows a wide range of toxicities but usually have relatively little oxidizing energy compared to chlorine.

CHLOROPHYLL - The green coloring material or pigments in plants that promotes the photosynthetic reactions forming organic materials from inorganic nutrients and light energy within the living cells.

CLARIFIER - A basin or chamber serving as an enlargement of a channel to reduce flow velocity sufficiently to permit separation of settleable or floatable materials from the carrier water (a sedimentation basin).

COAGULANT - A chemical, or chemicals, which when added to water suspensions will cause finely dispersed materials to gather into larger masses of improved filterability, settleability, or drainability.

COAGULATION - The process of modifying chemical, physical, or biological conditions to cause flocculation or agglomeration of particulates.

COD - A test for the estimation of the contamination of a wastewater in terms of oxygen requirements from a strong chemical oxidant under specified conditions, i.e., Dichromate, 50% sulfuric acid and 145°C for 2 hours.

COLIFORM GROUP - A group of bacteria that inhabits the intestinal tract of man, warm-blooded animals, and may be found in plants, soil, air and

the aquatic environment. Includes aerobic and facultative gram negative non-spore forming bacilli that ferment lactose with gas formation.

COLLECTION SYSTEM - The sewerage collection system is comprised of the conduits controlled by public agencies to intercept house, commercial or industrial discharges and transport them to a treatment facility or discharge point.

COLLOID, COLLOIDAL STATE - A state of suspension in which the particulate or insoluble material is in a finely divided form that remains dispersed in the liquid for extended time periods. Usually cloudy or turbid suspensions requiring flocculation before clarification.

COMBINED AVAILABLE CHLORINE - Generally refers to chlorine-ammonia compounds exhibiting a slower reaction with ortho toluidine, determinable with phenyl arsene oxide after addition of potassium iodide under acid conditions and usually requires higher concentration and longer time to kill in comparison with free available chlorine.

COMBINED SEWER - A sewer designed to carry wastewaters and storm waters in the same channel.

COMBINED SEWAGE - Consists of household, commercial or industrial wastes in combination with roof and surface storm drainage.

COMMINUTION -

- a) The act of cutting and screening materials contained in wastewaters.
- b) To reduce the size of fibrous or amorphous materials.

COMMINUTOR - A device for cutting sewage solids until they pass through an acceptable screen opening to improve pumping and wastewater processing.

COMPOUND -

- a) A combination of two or more atoms having definite physical and chemical characteristics and mutually attracted to each other.

- b) Atoms in the elemental state are electrically neutral but the number of external electrons may be increased or decreased in response to conditions and nature of the atom. An atom that becomes electrically charged may combine with another atom of opposite charge to form an electrically neutral compound.

CONCENTRATION -

- a) The act of increasing the mass per unit volume of one substance with respect to another, such as concentrating the solids in a sludge from 3% to 6%.
- b) A means of designating the ratio of one substance with respect to another, such as 15 mg of suspended solids per liter of water.

CONDITIONING - An action of improving possibilities for subsequent processing such as chemical treatment to improve sludge dewatering or filtering.

CONING - A condition in a clarifier sludge hopper where the solids concentrate or sludge is partially withdrawn to form a cone or channel through which clarified liquid is pumped out while most of the solids remain behind around the cone. Infrequent sludge pumping tends to encourage this condition where the sludge tends to solidify and is resistant to fluid flow.

CONTAMINATION - A general term referring to the introduction of materials into water that make the water less desirable for its intended use. Also introduction of undesired substances into air, solutions, or other defined media (chemical or biological).

CRITERION (pl. CRITERIA) - Something which can be measured. Commonly used as a basis for standards.

CROSS CONNECTION - In plumbing, a physical connection between two different water systems, such as between potable and polluted water lines.

CUBIC FOOT PER SECOND (c.f.s.) - A unit of discharge rate such as one cubic foot of gas per second past a given point.

CURVE -

- a) A graphic plotted to represent changes in value of one quantity in reference to another.
- b) A deviation from a straight line without a sharp break or angularity.

DATA - Records of observations or measurements of facts, occurrences and conditions in written, graphical or tabular form.

DEBRIS -

- a) The remains of something broken down or destroyed.
- b) An accumulation of fragments of rocks.

DECAY -

- a) To undergo decomposition.
- b) Implies a slow change from a state of soundness or perfection.
- c) To decay.

DEGRADE - To reduce the complexity of a chemical compound.

DEIONIZED WATER - Water that has been treated by ion exchange resins or compounds to remove cations and anions present in the form of dissolved salts.

DENITRIFICATION -

- a) The conversion of oxidized nitrogen (nitrate and nitrite-N) to nitrogen gas by contact with septic wastewater solids or other reducing chemicals.
- b) A reduction process with respect to oxidized nitrogen.

DETENTION PERIOD - The theoretical time required to displace the entire volume of a tank or basin at a given rate of discharge. Tank volume ÷ rate of discharge.

DETENTION PERIOD, ACTUAL - The actual time required for a given unit of liquid to flow through the tank or process unit. Usually determined by tracer method and depends upon inlet and outlet geometry, temperature, specific gravity, stratification, and other factors.

DETERGENT - Something used for cleaning. Commonly consists of soap or surfactant plus various additives or associated materials.

DETRITUS - The heavier material moved by natural flow, usually along the channel bed. Sand, grit or other coarse material.

DIAPHRAGM PUMP - A pump consisting of a rubber diaphragm (generally) fastened to a cylindrical casing having inlet and outlet valves. When the diaphragm is raised, liquid enters to be forced out the discharge valve on the reverse stroke.

DIFFUSED AERATION - Aeration produced by introducing air through a dispersing mechanism into a liquid. Sufficient air pressure must be applied to overcome hydrostatic head and diffuser or pipe back pressure.

DIFFUSOR - A porous plate, tube, bag, or other device, through which air is forced into a liquid in the form of small bubbles.

DIGESTED SLUDGE - Solids concentrates stabilized under aerobic or anaerobic conditions to preferentially decompose the more unstable fractions and produce a residue of satisfactory disposal characteristics. To reduce the volatile fraction of the sludge.

DILUTION -

- a) To make thinner or more liquid.
- b) A ratio, volume or weight of a more concentrated sample or effluent flow compared to that into which it is discharged.

DISINFECTION -

- a) To make free of infectious organisms.
- b) To kill disease organisms.

DISPOSAL -

- a) The discarding or throwing away.
- b) For wastewaters, this may represent any method of disposing, but usually involves some degree of degradation and discard in a non-pollutional manner.

DISSOLVED -

- a) Those materials dispersed in water in ionic, atomic, or molecular form; an homogenous mixture or solution.
- b) Generally clear but may be colored.
- c) Present in true solution form.

DISSOLVED OXYGEN (D. O.) - Dissolved molecular oxygen usually expressed in mg DO/l or percent of saturation.

DISTILLED WATER - A purified water resulting from heat vaporization followed later by vapor condensation to separate the water from non-volatile impurities.

DISTRIBUTOR -

- a) A device to control flow into some desired direction or place.
- b) A device used to spread the flow evenly across a trickling filter surface or other process unit.

DIVERSION CHAMBER - A basin or tank that may be used to divert part of the flow from a channel. May or may not contain treatment capabilities or a means of returning the diverted flow to the treatment plant when a shock load has passed.

DOSING SIPHON - A device to permit intermittent dosing, such as for a trickling filter. Consists of a chamber that will fill gradually to a fixed level before starting a siphon that permits rapid drainage to the filter or other treatment unit.

DRAINAGE TILE (Filter, or bottom tile) - A vitrified tile underdrainage system laid on the bottom to support trickling filter stone, sand, or other filter media, including sludge drying beds. These are specially prepared blocks or half-tiles containing slots for passage of water or air but restricting bed media penetration.

DRYING - The removal of water by natural or engineered means.

DYNAMIC HEAD, TOTAL - The difference in pressure at the elevation of the pump discharge and the elevation at the pump suction flange, plus the velocity head at the discharge minus the velocity head at the suction flange, all corrected to the same units and datum points.

ECOLOGY - The relation of an organism to its environment; i.e., how is an organism affected by his surroundings such as air, water, heat, noise, contamination, etc.

EFFICIENCY - The ratio of materials out of a process to those into that process usually expressed as a percentage.

EFFLUENT - A liquid or product water discharged from a chamber, basin or other treatment operation.

ELEMENT -

- a) Elementary substance.
- b) A substance or kind of matter in which all atoms are alike in that they will have the same average relative weight and the same number of external electrons.

ELUTRIATION - A washing operation. Sludge elutriation is an action where digested or process sludge is washed with sewage or effluent to remove fine particulates or certain soluble components. The elutriate is recycled to process waters, the elutriated solids are more readily filtered.

ENDOGENOUS METABOLISM - A diminished level of metabolism in which various materials previously stored by the cells are oxidized.

ENTERIC ORGANISMS - Those organisms commonly associated with the intestinal tract.

ENTRAINMENT - A condition or action that will cause an immiscible substance to be mixed with another. Usually the result of turbulence or entrapment; i.e., air bubbles in aqueous media.

ENZYME - A soluble or colloidal organic catalyst produced by a living organism. Usually they are simple or conjugated proteins that catalyze specific reactions.

EQUIVALENT -

- a) Equal in force, amount, or value.
- b) Chemical: The atomic or molecular weight of one substance that will react with one unit of weight of another substance; i.e., that weight of an

alkali necessary to precisely equalize 1 gram atomic wt. of H^+ ion.

EUTROPHIC - Well nourished; rich in dissolved nutrients.

EUTROPHICATION - An action involving the aging of lakes characterized by nutrient enrichment and increasing growth of plant and animal organisms. The net effect is to decrease depth until the lake becomes a bog and eventually dry land. Man-made pollution tends to hasten the process.

FACULTATIVE BACTERIA - Bacteria that can adapt themselves to growth and metabolism under aerobic or anaerobic conditions. Many organisms of interest in wastewater stabilization are among this group.

FAHRENHEIT - A temperature scale in which pure water at sea level has a freezing point at 32° and the boiling point is 212° .

FATS - Naturally occurring compounds functioning as storage products in the living organisms. Consist of carbon, hydrogen and oxygen in the form of fatty acid esters. Generally semi-solid or oily at normal temperatures.

FECAL COLIFORM - A group of organisms belonging to the coliform group and whose presence denotes recent fecal pollution from warm-blooded animals. Standard tests are available to differentiate the fecal coliform group from the other members of the group which have a lesser sanitary significance.

FERMENTATION - A form of respiration by organisms which requires little or no free oxygen, yielding alcohol and carbon dioxide as end products and releasing only part of the food energy available; i. e., the conversion of sugars into alcohol by enzymes from yeasts.

FILTER - A porous media through which a liquid may be passed to effect removal of suspended materials. Filter media may include paper, cloth, sand, prepared membranes, gravel, asbestos fiber, or other granular or fibrous material.

FILTER CLOTH - Fabric, wire or other material stretched over the drum of a vacuum filter and accessories to support the solids during cake formation and discharge the solids when and where desired.

FILTER FLOODING - The filling of a trickling filter with liquid to a level above the media by closing all outlet parts. Generally to control nuisance organisms such as flies.

FILTER FLY - Small black flies commonly found in or near the trickling filter. Commonly the Psychoda group.

FILTER LOADING - The mass (or volume) of applied oxygen demand or solids per unit of filter area or volume. See load ratio.

FILTER MEDIUM - Any material over which water sewage or other liquid is passed for purification purposes by chemical, biological or physical processes.

FILTER PONDING or CLOGGING - The effect of fine particles on sand filters or organic growth on trickling filters that restricts normal passage of liquid through the filter as a result of filling void spaces.

FILTER RESIDUE - That material which is retained on or in a filter.

FILTER UNLOADING - A phenomenon in which normally attached growth or slime on trickling filter media becomes detached and either partially or completely sloughs off.

FILTRATE - That liquid which has passed through a filter.

FILTRATION RATE - A rate of application of water or wastewater to a filter. Commonly expressed in million gallons per acre per day or gallons per square foot per min.

FINAL SETTLER, CLARIFIER - A settling basin or chamber for the mixed liquor following secondary treatment.

FLAME ARRESTOR - A safety device in the handling of flammable gases. Usually consists of an enlargement in a pipe line containing a metallic

- grid that allows passage of gas but acts as a barrier to the passage of flame.
- FLIGHTS** - A cross member of a conveyor system used for collection and transport of the collected material; i. e., the boards fastened to a chain loop on either side of a primary clarifier that pushes scum along the surface to a collector trough and sludge along the bottom to the sludge collector.
- FLOAT CONTROL** - Commonly a device to control a pump or pumps according to the water level in a chamber or well as indicated by the float. Usually operates a relay to control pump power, number, or speed of pumps in operation.
- FLOATATION** - A process for separation of solids from clarified liquid that causes particulates to be floated to the surface by means of attached air globules.
- FLOATING COVER** - A gas tight cover with a water seal supported by digester gas pressure and capable of moving upward or downward with liquid and gas content of the digester.
- FLOC** - Gelatinous or amorphous solids formed by chemical, biological or physical agglomeration of fine materials into larger masses that are more readily separated from the liquid.
- FLOCCULATION** - The gathering together of fine particulate materials in a suspension to form loosely associated larger masses of solids agglomerates.
- FLUME** - A long narrow channel for gravity flow of liquid from one point to another.
- FLY AWAY BOD** - Wastewater stabilization operations such as trickling filters encourage the development of insect larvae that serve as scavengers during their development. If the adult form of the larvae have functionable wings, the equivalent of oxygen demand consumed during development becomes fly-away BOD.
- FREE AVAILABLE CHLORINE** - Generally includes that chlorine existing in water as the hypochlorous acid. Characterized by rapid color formation with ortho-tolidine. Can be titrated in neutral solution with phenyl arsene oxide and produces a rapid organism kill in low concentrations.
- FREE BOARD** - The vertical distance from the normal water level in a flume, conduit, channel, basin, or other water enclosure, to the top of the confining structure.
- FRESH SLUDGE** - Recently deposited sludge from sedimentation tanks that has not been conditioned, processed, or progressed materially into the anaerobic action stage.
- FUNGI** - Simple or complex organisms without chlorophyll. The simpler forms are one-celled; higher forms have branched filaments and complicated life cycles. Examples are molds, yeasts and mushrooms.
- FWPCA** - Federal Water Pollution Control Administration, U. S. Department of the Interior.
- GAS DOME** - A chamber usually mounted on top of the digester cover for separation of gas from scum, foam or liquid.
- GAS HOLDER** - A tank used for storage of gas from sludge digestion units for the purpose of meeting the gas demand for burners, engines, or other use during non-steady production or use periods.
- GATE CHAMBER or GATE HOUSE** - A chamber installed for housing devices for controlling flow to various parts of a collection, treatment or distribution system, including valves, gates, and automatic or manual controls.
- GAUGE** -
- a) The action of measuring some item such as flow, level, size, rate, etc.
 - b) A device for gauging.
 - c) A size designation or indicator for some definite item such as 20-gauge wire, 16-gauge sheet steel.
- GERMICIDE** - An agent that kills micro-organisms.

- GRAVITY SYSTEM** - A system of open or closed conduits in which the liquid flows by gravity (without pumping).
- GRIT** - The heavy material in water or sewage such as sand, gravel, cinders, etc.
- GRIT CHAMBER** - An enlargement of a channel designed to reduce flow velocity adequately to permit differential separation of sand or grit from organic suspended material. Usually approaches a linear flow velocity of 1 to 3 ft/sec.
- GRIT COLLECTOR** - A device placed in a grit chamber to collect and to convey the more coarse and dense grit particles out of the chamber and permit return of most of the organic or liquid materials.
- HARDNESS** - Commonly refers to the chemicals interfering with soap action or producing scale in boilers or heating units. Specifically refers to Calcium and Magnesium salts; sometimes including iron, aluminum, and silica.
- HEAD LOSS** - The difference in pressure between the inlet and outlet pressure of a given process unit arising as a result of flow resistance within the process unit, such as the head loss due to friction of a filter media and filter residue.
- HEAT EXCHANGER COILS** - A piping layout designed to circulate a liquid media within the contents of the process unit but without mixing with the process media for the purpose of adding or removing heat; i.e., hot liquids may be circulated within a digester to raise digester temperature.
- HUMUS** - A brown or black complex and variable material resulting from decomposition of plant or animal matter.
- HYDROLYSIS** - The addition of water to any chemical compound. Commonly involved in splitting complex substances by addition of water to form more simple compounds.
- HYDROSTATIC HEAD** - The pressure exerted by a given height of liquid above a given datum point. May be listed in feet of head, pounds per square inch, or other criteria.
- IMPELLER** - A rotating set of vanes to impart motion to a fluid, commonly within a casing where dynamic energy of fluid increases from the center to the tip of the vanes. May be closed or open depending on a tube or paddle configuration.
- IMHOFF CONE** - A conical glass container commonly one liter capacity, having the upper larger diameter end open and the closed apex downward with graduations to assist estimation of the volume of settleable solids after an arbitrary time interval for settling (usually one hour).
- IMHOFF TANK** - A deep two-story tank originally patented by Karl Imhoff. The floor of the upper chamber is slotted for transfer of settleable solids from the settling chamber. The lower chamber serves for anaerobic digestion and storage of solids.
- INDICATOR** - May include the color change of a dye, electronic sensor response, or other means of estimating the equivalence point of a reaction between two different materials.
- INFILTRATION** -
- The entrance of ground water into a sewer through breaks, defective joints, or porous walls.
 - The penetration of water through the soil from surface precipitation, stream or impoundment boundaries.
- INFLUENT** - That material entering a process unit or operation.
- INORGANIC** - Being composed of material other than plant or animal materials. Forming or belonging to the inanimate world.
- INTERCEPTOR** - An intercepting sewer designed to carry the dry weather flow from a community to a treatment plant, but not large enough to carry storm water above some preset ratio to dry weather flow. May be used to collect lateral sewer flows.

LAGOON - A natural or artificial basin used for storage and/or stabilization of wastewater or sludge. Sometimes used for indefinite storage for disposal purposes. Commonly the lagoon depth is greater than a wadable depth but not greater than twenty feet.

LATERAL SEWER - A sewer that discharges into a branch or main sewer and has no other tributaries other than individual house connections.

LIQUID SLUDGE - An organic solids concentrate usually formed by deposition from wastewaters. The water content varies with the origin and nature of the sludge; usually has enough water to permit pumping but does not contain significant separatable free water.

LOAD - The load to a process is that which is contained in the inflow to that process. It may be expressed as hydraulic, oxygen demand, solids, or other criteria.

LOAD RATIO - An index of loading, including mass input per unit of capacity per unit of time. Mass may be expressed in lbs., BOD, COD, Susp. or volatile solids, capacity in volume, weight of solids or volatile solids in process, and time, usually in days.

LYSIS - To decompose, loosen, or separate into component parts.

MANHOLE - An opening by which access may be achieved for inspection, maintenance, or repair of a sewer, conduit, or other buried structure or appurtenance.

MANOMETER - An instrument for measuring pressure. Usually consists of a U-shaped tube containing a liquid, the surface of which moves proportionally in one open end with changes in pressure exerted upon the other end.

MECHANICAL AERATION - Aeration produced by mechanical energy of the turbine, pump, paddle, or other device that imparts an intimate mixture of liquid and air.

MEMBRANE FILTER - A flat, highly porous flexible plastic disc, commonly about 0.15 mm in thickness and 47-50 mm in

diameter. Membrane filters having a pore size of 0.45μ are used in water microbiology to trap organisms, and, by use of standard media and conditions, direct enumeration by colony count of selected organisms.

MENISCUS - The curved upper surface of a liquid in a tube that is concave upward when the containing walls are wetted by the confined liquid, and convex upward when they are not.

MESOPHILLIC - Medium temperature loving. Organisms capable of optimum metabolic activities at temperatures from about 80° - 110° F, 26° - 42° C.

METER - The length of a reference platinum bar used as a standard unit of measurement of length in the metric system. 1 meter = 39.37 inches.

MICRO - 1/1,000,000 of a unit of measurement, such as microgram, microliter.

MICROBIOLOGY - The science and study of microbiological organisms and their behavior. Commonly related to the study of pathogenic organisms.

MICROORGANISM - Commonly an organism too small to be observed individually by the human eye without optical aid.

MILLI- - An expression used to indicate 1/1000 of a standard unit of weight, length or capacity (metric system).

Milliliter (ml)	1/1000 liter (l)
Milligram (mg)	1/1000 gram (g)
Millimeter (mm)	1/1000 meter (m)

MILLI EQUIVALENT WEIGHT - 1/1000 of the equivalent weight; usually expressed in milligrams (mg).

MG/L - A unit of concentration on a weight/volume basis: Milligrams per liter. Equivalent to ppm when the specific gravity of the liquid is 1.0.

MIXED LIQUOR - A mixture of return sludge and wastewater in the aerator of an activated sludge plant. Also may be used in reference to mixed aerobic or anaerobic digesters.

MIXING ZONE - An area where two or more substances of different characteristics blend to form a uniform mixture; i.e., chlorine application, heated water, or other discharged materials entering a water mass will show significant differences of chlorine residual, temperature or other criteria, depending upon the sampling location throughout the mixing zone and approach uniform results with respect to lateral, longitudinal, and vertical sampling positions when mixing has been completed.

MOISTURE CONTENT - The content of water in some other material. Commonly expressed in percentage of moisture in soil, sludge or screenings.

MOST PROBABLE NUMBER (MPN) - A statistical method of determining microbial populations. A multiple dilution tube technique is utilized with a standard medium and observations are made for specific individual tube effects. Resultant coding is translated by mathematical probability tables into population numbers.

NITRIFICATION - The biochemical conversion of unoxidized nitrogen (ammonia and organic N) to oxidized nitrogen (usually nitrate).

NORMALITY -

- a) A means of expressing the concentration of a standard solution in terms of the gram equivalents of reacting substances per liter.
- b) Generally expressed as a decimal fraction, such as 0.1 or 0.02 N.

NUTRIENTS -

- a) Anything essential to support life.
- b) Includes many common elements and combinations of them. The major nutrients include carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorus.
- c) Nitrogen and phosphorus are of major concern because they tend to recycle and are hard to control.

ODOR CONTROL - In wastewater treatment this generally refers to good house-keeping in the plant and aeration,

chlorination or other operations to prevent onset of malodorous septicity in the wastewater flow.

OILS -

- a) Liquid fats of animal or vegetable origin.
- b) Oily or waxy mineral oils.

ORGANIC - Substances formed as a result of living plant or animal organisms. Generally contain carbon as a major constituent.

ORGANIC CHLORINE - Compounds containing chlorine in combination with carbon, hydrogen and certain other elements.

ORIFICE METER - A device consisting of a flange set in a pipe section containing an opening smaller than the pipe. Pressure readings above and below the orifice may be related to flow.

ORTHO TOLIDINE CHLORINE TEST - The dye, ortho toluidine, under highly acid conditions, produces a yellow color proportional in intensity to the concentration of available residual chlorine and certain other oxidants or interfering materials.

OUTFALL SEWER - The outlet or channel through which sewage effluent is discharged.

OXIDATION - Chemically: The addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound.

OXIDATION POND - A shallow basin employed for the stabilization of wastewaters.

OXYGEN AVAILABLE - That part of the oxygen available for aerobic stabilization of organic matter. Includes dissolved oxygen and that available in nitrite or nitrates, peroxides, ozone, and certain other forms of oxygen.

OXYGEN BALANCE - Refers to the dynamic relationship among the available oxygen assets and the oxygen requirements for stabilization of oxygen demanding materials in a treatment plant or receiving water.

OXYGEN DEPLETION - The loss of oxygen from water or sewage due to biological, chemical or physical action.

PARASITE - A living organism deriving its nutrients at the expense of another living organism, giving nothing in return.

PARSHALL FLUME - A device for estimation of the flow in an open conduit. Consists of a constricting section, a throat, and an expanding section. The throat contains a sill over which the liquid passes. The pressure change over the sill can be related to quantity of flow.

PARTICULATE MATERIAL - Refers to detectable solid material dispersed in a gas or liquid. Small sized particulates may produce a smoky or hazy appearance in a gas; milky or turbid appearance in a liquid. Larger particulates are more readily detected and separated by sedimentation or filtration.

PARTICULATES - Pertaining to small suspended solids in a gaseous or liquid media.

PARTS PER MILLION (PPM) - A unit of concentration signifying parts of some substance per million parts of dispersing medium. Equivalent numerically to mg/l only when the specific gravity of the solution is 1.0.

PATHOGENIC ORGANISMS - Bacterial, fungal, viral, or other organisms directly involved with diseases of plants, animals, or man, are included among this group.

PERCENTAGE TREATMENT - The ratio expressed as a percentage of the material removed from process water in terms of the material entering. Sometimes referred to as reduction.

pH - An index of hydrogen ion activity. Defined as the negative logarithm (base 10) of H^+ ion concentration at a given instant. On a scale of 0 to 14 pH 7.0 is neutral, pH less than 7.0 indicates a predominance of H^+ or acid ions; pH greater than 7.0 indicates a predominance of OH^- or alkaline ions.

PNEUMATIC EJECTOR - A device for pumping sludge, sewage, or other liquid by admitting the fluid into a chamber through one check valve and forcing it out of another by air pressure in the chamber above the liquid.

POLLUTION - Anything appearing in water that renders it unacceptable in terms of established water quality standards. Commonly conditions or contaminants that interfere with subsequent beneficial uses of the water.

POND - A basin or catchment used for retention of water for equalization, stabilization, or other purposes. Commonly less than five feet in depth.

PONDING - With reference to trickling filtration, ponding refers to a plugging of the filter media by slimes or solids to restrict downward movement of wastewater sufficiently to cause surface accumulation of liquid either partially or completely.

PRECIPITATE - The formation of solid particles in a solution, or the solids that settle as a result of chemical or physical action that caused solids suspension from solution.

PRESSURE - The total load or force acting upon a surface. In hydraulics, the term commonly means pounds per square inch of surface, or kilograms per square cm above atmospheric pressure on site. (Atmospheric pressure at sea level is about 14.7 pounds per square inch.)

PRIMARY SLUDGE - Sludge obtained from a primary sedimentation tank.

PRIMARY TREATMENT - Commonly the separation of settleable or floatable materials from carrier water. Usually preceded by pretreatment such as coarse screens, grit separation, comminution.

PROCESS - A series of operations or actions that lead to a particular result. A combination of unit operations that may be assembled and used for a given treatment objective.

PROTEINS - Naturally occurring compounds containing carbon, hydrogen, nitrogen, and oxygen, with smaller amounts of sulfur and phosphorus, and trace components essential to the living cells. An essential food associated with meat and eggs.

PROTOZOA - Single cell or multiple cell organisms, such as amoeba, ciliates, and flagellates. Commonly aquatic and generally derive most of their nutrition from preformed organic food.

PSYCHROPHILIC ORGANISMS - Low temperature loving organisms, or having a competitive advantage over other organisms at lower temperatures; i.e., from about 10°C downward to the freezing point.

PUTREFACTION - Biological decomposition of organic matter with the formation of ill-smelling products, such as H₂S, amines, mercaptans. Associated with anaerobic conditions.

QUIESCENT - Characterized by a lack of or negligible movement of the suspending media, such as liquid or gas. Still or absence of turbulence.

RAW WASTEWATER (SEWAGE) - Used wastewater prior to treatment.

RECIPROCATING PUMP - A pump device using a piston within a casing fitted with suction and discharge valves. Movement of the piston in one direction fills the casing, the reverse movement forces liquid into the discharge line. May be vertical or horizontal.

RECIRCULATION - The return of effluent to the influent of a process unit to reduce influent concentration, stabilize the system, maintain hydraulic flow, to reprocess, or for other beneficial reasons.

RECORDER -

a) A device to keep a continuous or intermittent record of some measured item such as flow, velocity, applied power, etc.

b) An individual who tabulates or maintains records of events, actions or measurements.

REDUCTION -

a) To make smaller or to remove from a given amount of material

b) Chemistry: The removal of oxygen, addition of hydrogen, or the addition of electrons to an element or compound.

RELIEF SEWER - A sewer built to carry the flow in excess of the capacity of an existing sewer.

RESIDUAL CHLORINE - See Available Residual Chlorine.

RETURN SLUDGE - Sludge returned from process to the influent flow. Commonly return activated sludge from a secondary clarifier. Also may include sludge from a clarifier after trickling filtration.

ROTARY DISTRIBUTOR - A device usually mounted on a center post with horizontal arms extending to the edge of a circular trickling filter for distribution of flow over the entire bed surface.

SALT - A chemical compound formed as a result of the interaction of an acid and an alkali (base). The commonest salt is sodium chloride formed from hydrochloric acid and sodium hydroxide. This ionizes in water solution to form Na⁺ and Cl⁻.

SANITARY SEWER - A sewer designed to receive and to convey household, commercial or industrial wastewater mixtures.

SAPROBIC, SAPROPHYTIC - Organisms living upon dead or decaying organic matter. Organisms that utilize non-living organic matter as a food.

SATURATION - Commonly refers to the maximum amount of any material that can be dissolved in water or other liquid at a given temperature and pressure. For oxygen, this commonly refers to a percentage saturation in terms of the saturation value, such as about 9 mg O₂/l at 20°C.

SCAVENGERS - Organisms that feed habitually upon refuse or carrion. In water pollution, this commonly refers to worms, insect larvae, bloodworms, sow bugs, and crustaceans. Or, more properly, oligochaetes, chironomids and isopods.

SCREEN - A device with openings, generally having a relatively uniform size, that permit liquid to pass but retain larger particles. The screen may consist of bars, coarse to fine wire, rods, gratings, paper, membranes, etc., depending upon particle size to be retained.

SCREENINGS - Material removed by the screens.

SCUM BOARD - A vertical baffle, above and below the liquid surface of a basin or tank, designed to prevent the passage of or to contain floating material within designated limits.

SCUM BREAKER - A device installed in a sludge digestion tank to disperse surface accumulations. Generally accomplished by means of mechanical agitation, gas or liquid recirculation, to promote mixing and destratification.

SCUM COLLECTOR - A mechanical device for skimming and removing scum or floatable material from the surface of a tank.

SECOND FOOT - An abbreviation for cubic foot per second. A rate term.

SECONDARY TREATMENT - Processes used to convert dissolved and colloidal materials in wastewater to a form that may be separated from the water. Commonly consists of biodegradation and conversion to cell mass in a separatable form with partial oxidation, such as in activated sludge, trickling filtration, or oxidation ponds.

SEDIMENTATION - The process of subsidence and deposition of suspended matter from wastewater by gravity. Also called clarification, settling.

SEPTIC SLUDGE - That sludge which has reached a stage of anaerobic putrefaction (sulfate reduction). Includes that from Imhoff, septic, or sludge digestion tanks.

SEPTIC WASTEWATER (SEWAGE) - Wastewater in which available oxygen has been depleted and the reduction of sulfates has begun. A result of anaerobic putrefaction.

SETTLABLE SOLIDS -

- a) Includes materials that will settle by gravity under low flow velocities.
- b) Commonly expressed in terms of the volume of solids accumulating in an Imhoff cone after one hour on a volume basis.

SETTLING BASIN - A natural or engineered enlargement of a channel that reduces velocity sufficiently to permit sedimentation of settleable particulates.

SEWAGE - See Wastewater.

SEWAGE GAS, DIGESTER GAS - The gas produced from anaerobic (septic) sewage solids. Generally contains marsh gas (methane) and carbon dioxide with hydrogen sulfide and other components in minor proportions.

SEWER - A pipe or conduit, generally covered, for the purposes of conveying wastewaters from the point of origin to a point of treatment or discharge.

SEWERAGE SYSTEM - A system of sewers and appurtenances for the collection, transportation and pumping of used waters for a given area or basin. Any treatment device or facility and its outfall conduit are a part of the system.

SHORT CIRCUITING - Hydraulic: A condition in which one part or unit of flow into the basin reaches the outlet in much less time than that required for a uniformly mixed flow. Electrical: A situation in which an electric current is out of place in relation to its controlled pathway.

SLIME - SEWAGE SLIMES - Consisting of organisms growing on wastewater nutrients with the formation of mucilaginous covering, streamers or clumps. May consist of bacteria, molds, protozoa or algae.

SLOUGHING - A phenomenon associated with trickling filters and contact aeration units where slimes build up to a varying degree, then slip off into the effluent.

SLUDGE - Accumulated or concentrated solids from sedimentation or clarification of wastewater. Contains varying proportions of solids in wastewater depending upon source, process, and nature.

SLUDGE BANKS - An accumulation of solids including silt, mineral, organic, and cell mass particulate material, that is produced in the aquatic system characterized by low current velocity. Generally refers to gross deposits of appreciable depth.

SLUDGE CAKE - The solids remaining after dewatering sludge by vacuum, filtration, or sludge drying beds. Usually forkable or spadable, with a water content of 30 to 80%. Also may occur on the boundaries of surface water.

SLUDGE COLLECTOR - A mechanical device, including rake, drag, or suction, for collecting settled sludge from the bottom of a clarifier into a sump or other withdrawal system.

SLUDGE DIGESTION - A process by which organic matter in sludge is converted into more stable or separatable form through the action of living organisms. May be the result of aerobic or anaerobic digestion.

SLUDGE DRYING BED - An area used to discharge wet sludge for drainage and drying. Generally prepared of porous bed material surrounded by sidewalls to contain the sludge while the liquid percolates into an under-drain system. May be covered or uncovered.

SLUDGE FILTER - A device to effect partial water removal from wet sludge, usually with the aid of vacuum or pressure of preconditioned sludge.

SLUDGE SYNTHESIS - The net gain in sludge mass in a process over a period of time as a result of simultaneous growth of cell mass and endogenous oxidation within it.

SLUICE GATE - A gate constructed for adjustment to control the flow in a channel by gate position.

SOLUTION -

a) An homogenous mixture, commonly gas, liquid, or solid in a liquid that remains clear indefinitely.

b) Generally an atomic, ionic, or molecular dispersion in a liquid (may be colored).

c) A water solution of dissolved material.

SPECIFIC GRAVITY (Sp. Gr.) -

a) The weight of a material per unit volume in reference to the weight of water at maximum density.

b) Water at 4°C has a weight of 1g per ml. The weight ratio of any substance divided by the weight of water is the specific gravity.

SQUEEGEE -

a) A device, generally rubber, used for dislodging and removing solids, scum or other materials from a surface.

b) Metal or wood blades to move sludge solids along the bottom of a clarifier.

STABILITY -

a) The ability of any substance to resist putrefaction.

b) Ability of an engineered structure to resist distortion or overturn when loaded.

STABILIZATION -

a) The activity proceeding along the pathway to stability.

b) In organic wastes, generally refers to oxidation via biochemical pathways and conversion to gaseous or insoluble materials relatively inert to further change.

STANDARD - Something set by authority. Having qualities or attributes required by law and defined by minimum or maximum limits of acceptability in terms of established criteria or measurable indices.

STANDARD METHODS - Methods of analysis prescribed by joint action of APHA, ASCE, AWWA, and FWPCA. Methods accepted by authority.

STEP AERATION - A procedure for adding increments of wastewater at various points along the line of flow in an activated sludge aerator.

STERILIZATION - The process of making a medium free of living organisms such as by killing them, filtering through a porous medium fine enough to be a barrier to the passage of organisms, etc.

STORM OVERFLOW - A device such as a weir, dam, or orifice, in a combined sewer that will intercept design flow but permit excess storm flow to discharge directly. The overflow contains a mixed discharge of storm and other sewer components.

STORM SEWER - A sewer which carries storm water from roofs, surface wash and street drainage.

STUCK DIGESTER - Any of a series of events that results in serious malfunction of the digester. Commonly refers to anaerobic digestion where overloading, temperature control, toxicity, or other factors, result in an excessive acid production with serious limitations of gasification, stabilization, and solids concentration.

SUBSTRATE -

- a) The base or media in which an organisms lives.
- b) The liquid in an activated sludge aeration tank.

SUPERNATANT LIQUOR - The liquid overlying deposited sludge. Commonly that fraction of liquid in an anaerobic digester located over the deposited material and beneath possible surface floating material.

SURFACTANT -

- a) A chemical that, when added to water, will greatly reduce the surface tension of the solution.
- b) The surface active component in a detergent mixture.

SUSPENDED SOLIDS - The concentration of insoluble materials suspended or dispersed in waste or used water. Generally expressed in mg/liter on a dry weight basis. Usually determined by filtration methods.

SYNERGISM - Refers to the action produced when two or more substances in combination have a greater effect than that produced by the additive effects of each one separately.

TAPERED AERATION - A procedure for adjusting air input along the line of flow of an activated sludge aerator according to need. Usually requires addition of more air per unit of volume at the inlet end of the aerator.

TERTIARY TREATMENT - See Advanced Waste Treatment.

THERMAL POLLUTION - Refers to heated discharges to surface waterways. The largest contributor of heated discharges is associated with power production.

THERMOPHILIC - High temperature loving organisms. Generally considered to include organisms having a favorable competitive advantage at temperatures above 110°F or 42°C.

THIEF - A term applied to a sampling tube used to remove a core of sample from a bag or bulk material.

TITRATION - The careful addition of a standard solution of known concentration of reacting substance to an equivalence point to estimate the concentration of a desired material in a sample.

TOC - Total Organic Carbon. A test expressing wastewater contaminant concentration in terms of the carbon content.

TOTAL SOLIDS - Refers to the solids contained in dissolved and suspended form in water. Commonly determined on a weight basis by evaporation to dryness.

TRICKLING FILTER - A treatment process employing downward flow of wastewater over the surfaces of a rock or grid system with a large void space for upward movement of air. Slime organisms accumulate to effect biological stabilization.

UNIT OPERATION - A particular kind of a physical change that is repeatedly and frequently encountered as a step in a process such as filtration, aeration, evaporation, mixing, or pumping.

UNITS OF MEASUREMENT -

English - foot, pound, second.
Metric - centimeter, gram, second.
Abbreviations: ft., lb., sec.
cm., g., sec.

USPHS - United States Public Health Service, Department of Health, Education and Welfare.

USPHS DRINKING WATER STANDARDS - A list of standards prescribed for potable water acceptable for use on interstate carriers. Deal with sources, protection, and bacteriological, biological, chemical and physical criteria--some mandatory, some desired. Official for municipal use only upon acceptance by State and local authorities.

VELOCITY (FLOW) - A rate term expressed in terms of linear movement per unit of time. Commonly expressed in ft per sec (English) or cm/sec (Metric).

VENTURI METER - A device for estimating flow of fluid in closed conduits or pipes. Generally based upon constricting and enlarging pipe sections with pressure at the full size and the point of maximum constriction. Differences in pressure can be related to flow.

VIRUS - A term generally used to designate organisms that pass filtration media capable of removing bacteria. Technically described as a collective term covering disease stimuli held by some to be living organisms and by others to be nucleic acids capable of reproduction and growth.

VOLATILE ACIDS - A group of low molecular weight acids such as acetic and propionic, that are distillable from acidified solution.

VOLATILE MATERIAL -

a) Refers to those chemicals having a vapor pressure low enough to evaporate from water readily at normal temperatures.

b) With reference to dry solids, the term includes loss in weight upon ignition at 600°C.

VOLATILE SOLIDS - The quantity of solids in water that represents a loss in weight upon ignition at 600°C.

WASTEWATER - Refers to the used water of a community. Generally contaminated by the waste products from household, commercial or industrial activities. Often contains surface wash, storm water and infiltrations water.

WASTE SLUDGE -

a) Commonly refers to activated sludge produced in excess of that required for return process.

b) Any solids concentrate to be routed for disposal.

WATER QUALITY CRITERIA - Includes selected analytical measurements with limits designated to be acceptable or unacceptable in reference to water quality standards.

WATER QUALITY STANDARDS - Limits set by authority on the basis of water quality criteria required for beneficial uses.

WEIR - A device used for surface overflow from a tank, basin or chamber. Generally designed to smooth out discharge flow to minimize turbulence within the detention basin. May be used to measure discharged flow.

WEIR BOX - An enlargement of the channel upstream of a weir to reduce the velocity and turbulence before reaching the weir.

WELL -

- a) An artificial excavation or shaft that collects water from interstices of the soil or rock.
- b) Also an engineered structure for the housing of pumps or other equipment below ground level.

WET OXIDATION - Oxidation of substances such as organic contaminants in water media. Includes biological oxidation and physical chemical oxidation, such as that obtained at elevated temperature, pressure, catalyst or other promoters.

WPCF - Water Pollution Control Federation. An organization composed of individuals engaged in the advancement of knowledge in research, design, operation, and control of water pollution in relation to man and his environment.

YIELD -

- a) To give up or relinquish.
- b) To bear or bring forth as a result of cell division.
- c) To produce as a result of investment of energy, materials, or time.
- d) The amount or quantity produced per unit of raw material.

YIELD FACTOR - A decimal fraction or percentage of product per unit of input.

ZOOGLUEA - A jelly-like matrix developed by certain microorganisms at some stage in their life cycle. Commonly associated with sludge flocculation in biochemical treatment operations.

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